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Fixing development

Breakdown, repair and disposal in Kenya's off-grid solar market

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Declaration

I declare that this thesis has been composed solely by myself and that it has not been submitted, in whole or in part, in any previous application for a degree. Except where stated otherwise by reference or acknowledgment, the work presented is entirely my own.

Signed: [redacted]

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For the *mafundi* of Kenya

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Abstract

The development project is a repair project. Schemes and initiatives to improve the human condition are borne from the belief that there is something broken in the status quo that we must fix. Small solar-powered products are one such fix. Portable lanterns and multi-light home systems are being distributed across sub-Saharan Africa, particularly in rural areas, as part of efforts to reach universal energy access - a long-standing challenge of development. Yet these products themselves, like all things, break down. This thesis follows off-grid solar products in Kenya from moments of breakdown through sites of use, repair and disposal.

The first half of the thesis looks at the historical development of the technology and the market that has grown up with and around it. Assemblage thinking shows that breakdown is more than a material process but is shaped by wider influences such as business and product design as well. The second half of the thesis describes what happens to the broken down solar product as it moves and is moved through Kenya. Despite differences in appearance and process in three different settings – the home, the repair clinic and the company - the thesis finds consistencies in people's responses to breakdown. These consistencies appear as a form of *bricolage* as people draw on previous experience and make use of resources at-hand to reach an acceptable, if at times limited, functionality for their products. Disposal of that which is not repaired is found to always be prefaced by an indefinite period of waiting.

The thesis is based on 16 months of fieldwork across the country which included observation of independent and company repair practices and rural and urban waste management processes. 44 interviews were conducted with independent repairmen, company representatives and other relevant individuals. Further information is drawn from a telephone survey of 262 users of solar products.

If the macro project of international development is to fix the broken world, then this thesis argues it may benefit from closer examination of micro repair practices. By embracing the inevitability of future breakdown and adopting the principles of *bricolage* development might get closer to the improved world it aims for.

Keywords: breakdown, repair, waste, solar, off-grid, Kenya, Africa, bricolage

Lay summary

International development schemes and initiatives whether they are led by governments, charities, UN agencies or social enterprises all acknowledge that the world is not right, it is broken. One way in which the world is broken in the eyes of development practitioners is that not everyone has access to electricity. Although electrification has been a target of development efforts for a long time one relatively new response to the problem has been to provide small, household-level solar products. These solar products, which can light a few rooms and charge mobile phones or televisions have mainly been distributed by businesses. However, like all electronics these solar products break down. This thesis looks at why they break down and what happens when they do.

The first half of the thesis describes the history of solar power in Kenya and outlines what the market looks like in the country today: who is selling what and how. Although we normally think of breakdown as being a physical process; a cable being torn or maybe a battery going dead there are other types of breakdown too, like people stealing solar panels. The second half of the thesis describes what happens to broken down solar products in homes, independent repair shops and on company premises. In doing so it is shown that people respond to break down similarly in these three locations. People use their own past experience and any resources they have to hand to get their solar products working again even if not as well as before. When they cannot repair it people in each location generally hold on to the product while they decide what to do with it.

The thesis is based on nearly one and a half years of research in Kenya. This included spending time with repairmen in their shops and following waste workers and scrap collectors on their rounds. Interviews were done with 44 repairmen, solar company employees and other relevant individuals. The third method used was a telephone survey of 362 users of solar products, some of these users were then visited at their homes.

The thesis argues that international development responds to breakdown differently than people in Kenya. Rather than use existing resources development tends to introduce whole new systems. The research suggests that development might be more successful if it worked more like users, repairmen and technicians do with their solar products.

Abbreviations and acronyms

AECF	Africa Enterprise Challenge Fund
ABM	Associated Battery Manufacturers
Ah	Amp-hour
a.m.	*ante meridiem,* before noon
AMREF	African Medical and Research Foundation
BBC	British Broadcasting Corporation
BoP	Bottom of the Pyramid
ca.	*circa*, about, approximately
CBD	Central Business District
CBO	Community-based organisation
CD	Compact Disc
CEO	Chief executive officer
CNN	Cable News Network
CRT	Cathode ray tube
CSR	Corporate social responsibility
DFID	Department for International Development
DIY	Do-It-Yourself
DVD	Digital Video Disc
EAA	Energy Alternatives Africa
EABC	East African Business Council
EAC	East African Community
e.g.	*exempli gratia,* for example
EnDev	Energising Development
EoL	End-of-life
EPI	Extended Programme on Immunisation
ERC	Energy Regulatory Commission
ESMAP	Energy Sector Management Assistance Program
et al.	*et alia,* and others
etc.	*et cetera,* and so forth
EU	European Union
FMCG	Fast-Moving Consumer Goods
FOIA	Freedom of Information Act
GHGs	Greenhouse gases
GIZ	*Gesellschaft für Internationale Zusammenarbeit*
GOGLA	Global Off-Grid Lighting Association
GTZ	*Gesellschaft für Technische Zusammenarbeit*
IC	Integrated circuit
i.e.	*id est*, that is
IEA	International Energy Agency
IEC	International Electrotechnical Commission
IFC	International Finance Corporation
INGO	International non-governmental organisation
IoT	Internet of things
IP	Ingress protection
IRENA	International Renewable Energy Agency
IRIS	Impact Reporting and Investment Standards
ISM	Import Standardisation Mark

ITDG	Intermediate Technology Development Group
KCYP	Kibera Community Youth Project
KEBS	Kenya Bureau of Standards
KEPSA	Kenya Private Sector Alliance
KEREA	Kenya Renewable Energy Association
KIRDI	Kenya Industrial Research and Development Institute
KTDA	Kenya Tea Development Agency
KWFT	Kenya Women Finance Trust
kWh	Kilowatt hour
KWS	Kenya Wildlife Service
LCD	Liquid crystal display
LED	Light-emitting diode
LEIA	Low-Energy Inclusive Apppliances
MDGs	Millennium Development Goals
MENA	Middle East and North Africa
MFI	Microfinance institution
MP	Member of Parliament
NASA	National Aeronautics and Space Administration
NGO	Non-governmental organisation
OECD	Organisation for Economic Co-operation and Development
PAYG	Pay-As-You-Go
PCB	Printed circuit board
p.m.	*post meridiem*, after noon
PSP	Pico-Solar Product
PV	Photovoltaic
PVMTI	Photovoltaic Market Transformation Initiative
RISSEA	Research Institute of Swahili Studies in Eastern Africa
SACCO	Savings and credit cooperative organisation
SDGs	Sustainable Development Goals
SHS	Solar Home System
sic	so, thus, in this manner
SMS	Short Message Service
SNV	*Stichting Nederlandse Vrijwilligers*
STS	Science and Technology Studies
SVTC	Silicon Valley Toxics Coalition
TV	Television
UAE	United Arab Emirates
UN	United Nations
UNDP	United Nations Development Programme
USA	United States of America
USAID	United States Agency for International Development
USB	Universal Serial Bus
USSD	Unstructured Supplementary Service Data
VAT	Value-added tax
W	Watt(s)
WEEE	Waste Electrical and Electronic Equipment
WHO	World Health Organisation

Introduction

Development and the broken world

The Solar Assemblage

Electrification has long been at the heart of the world-improving project of international development. Improving standards of living, health, education and economic output as international development is wont to do (1: Peet and Hartwick, 2015; 3: Sen, 2001) can all be aided by the presence of electricity (Kanagawa and Nakata, 2008). The visible elements of electricity (pylons, cables and power plants) have also been used historically to signify state power and modernity (15: Cunningham and Kearney, 2016) which has kept electrification prominent on domestic development agendas too (Kale, 2014). However, despite being a regular priority on domestic, bi- and multi-lateral agendas since the end of the Second World War, a number of countries in the Global South do not have 100% electrification rates, either by reach (all areas connected) or provision (a constant and consistent supply).[1] The electrification project has proven particularly challenging in rural areas where settlements can be more dispersed, energy demand lower and income levels are generally lower as well (see Chaurey et al., 2004). This in addition to political challenges of governance, corruption and local socio-political dynamics (Pless and Fell, 2017).

In the face of slow grid expansion and unreliable electricity grids, *off*-grid solutions to electrification have emerged. Improvements in battery chemistries and ever-falling prices of solar panels have made solar photovoltaic technology a popular and economically viable option for un-electrified rural areas (Singh, 1991).[2] This is particularly true for sub-

[1] The term 'Global South' is used here, and at other points in the thesis, to refer to countries that have also been described as 'Third World', 'developing' or 'less developed'. Unlike some of these other terms, Global South attempts to move away from a hierarchical ranking or comparison of countries towards a term that reflects the connected nature of these countries in a globalised world. The Global South includes parts of South America, Sub-Saharan Africa and South Asia (Dados and Connell, 2012). One thing in common for countries in this group is their experience of development interventions most often led and financed by organisations and institutions based in the 'Global North' (largely North America and Europe).

[2] Solar photovoltaic (PV) technology uses light from the sun to generate electric energy as opposed to other forms of solar power such as solar thermal where it used to generate heat. 'Photo' means light and 'voltaic' means electric. In some places solar photovoltaic is referred to alternatively as 'solar electric' or 'solar photo-electric'.

Saharan Africa where solar irradiance (light energy from the sun) is over 2,000 kilowatt hours per metre squared (kWh/m^2) per year and most of the population is rural (World Bank, 2016; World Bank, 2018c).[3] In addition to community-level mini- or micro-grids powered by solar panels, these off-grid solar options include products targeting individual households.

The material shift in form from grid to off-grid solutions has been mirrored with a shift in language from electrification to energy access. In 2015 for instance when the United Nations Development Programme (UNDP) launched a new agenda for international development, the seventh of its 17 goals, Sustainable Development Goal (SDG) 7, was to: "Ensure access to affordable, reliable, sustainable and modern energy for all" (21: United Nations, 2015a). Where 'electricity' implied a mains electricity grid, 'energy' includes alternative sources and forms of electricity, such as off-grid systems.[4]

Off-grid solar solutions at the household-level are referred to in industry and in research according to their size as: solar lanterns, pico-solar products (PSPs) and solar home systems (SHSs) (238: Hansen et al., 2015; xvi: Dalberg Advisors and Lighting Global, 2018). Materially the differences across these categories are minimal. The panels (which are at times integrated in to the same unit as the light and battery) are made from crystalline silicon and can be anything up to 350 watts (W) in size. The casings are generally of smooth, bright-coloured plastic with rounded edges. The most variation is in the battery. Lithium ion, lithium fero-phosphate and lead acid are the most common types, with capacities of up to 10 Amp-hours (Ah). Operationally the objects are the same too: light lands on the solar panel where it is converted in to electrical energy which is stored in the battery and later released to activate one or more light-emitting diode (LED) or to charge another battery in a phone, radio or television (TV). The three types of object - lantern, PSP and SHS - are manufactured, distributed and sold alongside each other by the same companies and organisations. Reflecting these broad similarities this thesis uses the single term 'off-grid solar product' to refer to the range of models under discussion.[5]

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[3] A kilowatt hour is a measure of energy equivalent to 1000 watts of power being sustained for one hour. The annual average for solar irradiance in Europe is half that of sub-Saharan Africa at nearer to 1,000 kWh/m^2 (World Bank, 2016).

[4] Energy access also covers fuel sources and technologies for domestic cooking.

[5] Early in the research for this thesis I debated focusing on just solar lanterns or just solar home systems. This was partly because previously there were some companies which focused on one or the other and the pico- segment between the two was not as established as it is now. There are still some differences in how the solar lanterns and solar home systems are regarded though and these are drawn out in later chapters. Users more commonly refer to off-grid solar products as *taa*s

In 2010 while director of the British Museum, art historian Neil MacGregor, chose an off-grid solar product as the '100th object' in an exhibition called: *A History of the World in 100 Objects* (MacGregor, 2011). MacGregor described it thus

> [The product] is in fact a little kit, consisting of a plastic light containing a rechargeable six-volt battery and a separate, small photovoltaic panel. The lamp has a handle and is about the size of a large mug, and the solar panel looks like a smallish silver photo frame – the sort you see on a desk or a bedside table.

MacGregor's description of the d.light Nova S200 (fig. 0.1) draws attention to the multiple parts the object is made of.

Figure 0.1 The 100th Object, the Nova S200 (Jamie Cross, 2012)

Although stripped of its brand and market context for the purposes of the exhibition (Cross, 2013) the Nova S200 is actually one of hundreds of different models of solar lamps that are

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(lamp/lantern) or d.lights – one of the most established and best-selling brands. This is because for many Kenyans the off-grid solar product is not solar at all. For them 'solar' refers to a solar panel (which has been available in the country for much longer) that is attached to a lead acid battery as part of what are sometimes called component-based systems (xvi: Dalberg Advisors and Lighting Global, 2018). Off-grid solar product is still chosen here to avoid confusion with other uses of *taa* such as torch and to be able to discuss d.light as one brand among many. Finally, off-grid solar is a description used by many actors in the industry to describe the technology.

being marketed, sold and distributed to 1.1 billion people worldwide who live without ready access to electricity (11: OECD and IEA, 2017). In addition to providing light the Nova S200 can charge a mobile phone. Similar but smaller models only offer lighting (solar lanterns) while other, larger kits (solar home systems) can charge accessories like radios and TVs in addition to the mobile phone (fig. 0.2).

Figure 0.2 A typical Solar Home System (M-Kopa, 2014)

However, rather than incorporate these less visible, less iconic and less centralised off-grid options for energy access into policy most African governments continue to push programmes of grid-based electrification, often through designated rural electrification agencies. As a result, most distribution of off-grid solutions has been led by non-governmental organisations (NGOs) and private companies, often from outside the country. We might refer to these actors and institutions collectively as a global off-grid solar industry.

The marketing, sale and distribution of these products has caught the attention of media outlets and financial investors outside of the region. After a radio series to accompany MacGregor's exhibition (xiii: MacGregor, 2011) the British Broadcasting Corporation (BBC) has since run several stories and reports on the off-grid solar industry that the 100th object, the Nova S200 came from (Heap, 2013; Jackson, 2015; Nuwer, 2017;

BBC, 2018). Along with other prominent media outlets such as Cable News Network (CNN; Prisco, 2016), the Economist (The Economist, 2016) and the New York Times (Okonjo-Iweala, 2015), the BBC coverage tells an optimistic story of the potential of the global off-grid solar industry to bring "power to the people" (BBC, 2018). The academic, grey and industry literature is similarly positive in assessments of the impacts these products can have on health (e.g. Obeng et al., 2008), education (e.g. Kanagawa and Nagata, 2008), gender (e.g. Cabraal et al, 2005) and economic (e.g. SolarAid, 2015a) indicators. The narratives in these press, industry and academic publications help raise awareness of the industry and bring in financial support and investment from individuals and institutions alike. In the two years to 2018 off-grid solar companies raised $500 million (1: Dalberg Advisors and Lighting Global, 2018). But this surrounding investment of excitement and finance is not captured in a material description of the object, like that given by MacGregor. Instead, as anthropologist Jamie Cross, reminds us:

> Since the 1980s, social studies of science and technology have urged us to see an object like this as more than an assemblage of microelectronic components, and to engage with the complex array of knowledge practices, social relationships and meanings that enable the Nova S200 to convert sunlight into electrical energy and achieve its range of purported effects. (369: Cross, 2013)

In other words, we are invited to bring the culture surrounding these products together with the parts and materials into a socio-material solar assemblage. Cross introduces the solar assemblage as a concept in a blog post titled 'The Solar Assemblage' (Cross, 2012). In the blog post Cross sets out the socio-material relationships that the off-grid solar product is entangled with. This thesis builds on the concept by providing some of the first empirical evidence of its existence and extends our understanding from the assemblage's formation which Cross describes to its breakdown, repair and disposal.

Although not always using the language of the assemblage, scholars of rural electrification (more recently energy access) and those working towards an anthropology of energy have long recognised the dependency of electricity provision on both material hardware and social or institutional arrangements (Lorenzo, 1997; Pellegrini and Tasciotti, 2013; Peters et al., 2009; Winther, 2008). Electricity cannot provide itself however nor does it do so automatically; the solar panel does not install itself. Instead there is a plethora of individuals, companies, marketing campaigns, NGO projects, lobbying efforts and other activities that form part of the story. Even when electricity is provided it is only useful if it passes through a lightbulb, a television, a refrigerator or any number of electrical

appliance that an end-user can benefit from. But those appliances only reach the user through processes of manufacture and sale, processes that are themselves regulated by various national, regional and international authorities and entities. Although off-grid solar products are smaller than substations and their parts are less prominent than pylons,[6] thinking of a solar assemblage keeps visible the series of social relations and interactions between people and things that collectively provide energy off-the-grid.

This thesis follows the definition of assemblage laid out by philosopher Thomas Nail. In the article *What is an Assemblage?* Nail formalises the idea as first articulated by French philosophers Gilles Deleuze and Félix Guatarri in *A Thousand Plateaus: Capitalism and Schizophrenia* (Nail, 2017). Nail outlines three components in the structure of an assemblage: relations, concrete elements and agents (24: Nail, 2017). The agents, according to Nail, are the collective third-person subjects (we, one, everyone) that arrange and give meaning to the relations and concrete elements. For the solar assemblage the agents are the roles such as users, designers, manufacturers, financiers, retailers, lobbyists, regulators, fundraisers, journalists, researchers etc. The concrete elements are the embodiment of the assemblage. In this case the concrete elements are the off-grid solar products, the people (rather than their roles), the companies and the market institutions. The relations, or "abstract machine" to use Deleuze and Guatarri's term, connect the concrete elements with the agents by giving them a proper noun. In this thesis, the abstract machine is the off-grid solar industry.

Assemblage is useful when studying electricity because of its emphasis on relations[7]. Despite their more discrete material form when part of an off-grid system as opposed to a grid-based one where the lines are visible to the human eye the assemblage helps keep sight of the connections that are integral to the delivery of electricity. In both off- and on-grid forms, electricity, like any infrastructure, requires continual upkeep, maintenance and attendance to those relations to keep the electrons flowing. Electrification does not end the moment a house is connected to a grid or the solar panel is installed: that plethora of relationships has to keep working. There are however times in off-grid as in on-grid systems when relations break down and electrification is interrupted.

[6] A substation is a location, between a power station and a consumer, at which an electric current is switched, transformed or converted typically from a high to low voltage (OED, 2018).

[7] Although using the terms "system" and "apparatus" rather than "assemblage", Escobar (1995) and Ferguson's (1994) studies also emphasise the relations between actors, institutions and, crucially, discourse that constitute development in India and Lesotho respectively.

This breakdown, like the relations themselves, can also be less visible in off-grid settings where power cuts are not uniform across a neighbourhood or community as they would be in a grid system. Assemblage thinking might also be helpful then in examining off-grid power cuts; moments and processes where relationships within the assemblage shift, strain and break down. Jane Bennett does precisely this in a grid-setting with her study of the North American Blackout of August 2003 (Bennett, 2005). Much like the broad range of actors and services understood to make and maintain electrification, Bennett shows how responsibility for disconnection is also distributed across and through the assemblage. In addition to taking the assemblage approach to look at blackouts, or breakdowns, off-the-grid, this thesis takes it a step further to explore how the solar assemblage *responds* to breakdown: is it fixed? How? And if not, what happens?

Geographer Anna Davies asks similar questions of off-shore windfarms, wondering what happens when renewable energy technologies need to be: "decommissioned, deconstructed and disposed of." (194: Davies, 2012). What happens, Davies asks:

> when the materials are worn out or damaged and need to be replaced? Where will these end-of-life smart materials go, in what ways will their composition decompose over time and what regulatory and technical frameworks will be required to contain them? Essentially, what will be the new spatial signatures of these novel end-of-life materials? (194; Davies, 2012)

These are ethically important questions for social and environmental reasons. Socially, not having answers to Davies' questions means potentially leaving users once more without energy access. Environmentally, not knowing or not preparing for what will happen means potential contamination by way of disposal of plastics, electronic components and batteries in local ground and water resources. One estimate suggested that there were 400 tonnes of 'off-grid solar waste' in 2014 (2: Magalini et al., 2016). The same report estimated that this would rise to 3,600 tonnes by 2017 (27: Magalini et al., 2016). Some of that 3,600 tonnes is featured in this thesis.

Broken products and broken provision

Beyond the products themselves (micro level) there are concerns around their provision as well (macro level). The delivery is broken because it is, in many ways, neo-colonial. Borne out of development with its own basis in Western history and experience (see Escobar, 1995), the provision of off-grid solar products propagates many of the same dynamics

around where expertise is located and who holds authority. The off-grid solar industry sees and sets up Africa as a place of absence (see Mbembe, 2001). In doing so actors within the industry are able to establish a particular understanding of what the problem is (slow grid expansion) and so what the solution must be (off-grid solar products). This process is reminiscent of the de-politicisation thesis put forward by James Ferguson in his seminal work: *The Anti-Politics Machine* (1994). Unlike Ferguson found in Lesotho however the provision of solar in Kenya is not, at least by the market's own measures, failing. Indeed, sales volumes, investment and product performance are all moving up and to the right; increasing. However, like in Lesotho, there are unintended consequences of these interventions: on one level this is the problem of waste and on another it is the reproduction of global inequalities. The breakdowns explored in this thesis then are both material (surrounding the solar product) and political (surrounding its provision). Working with assemblage thinking helps keep these two strands together. This thesis explores the entanglement of these micro and macro breakdowns and towards the ends moves to discuss how those breakdowns might be responded to, if not repaired.

The next section of the introduction connects the solar assemblage outlined above to existing literature that focuses on infrastructure, markets and repair.[8] The introduction then introduces the three research questions at the centre of the thesis before explaining and justifying the 'follow the thing' methodology through which the research was conducted and the research questions answered. The introduction closes with a chapter-by-chapter overview of the rest of the thesis that follows the off-grid solar product through the solar assemblage from homes to independent repair clinics and on to company offices, workshops and warehouses.

[8] The expansive literature on the topic of energy access is not directly engaged with here. This is because much of the energy access literature is concerned with project implementation or evaluation (e.g. Brew-Hammond and Kemausuor, 2009; Brew-Hammond, 2010; Hancock, 2015). Although this thesis does comment on the impact of the off-grid solar industry, particularly concerning the wastes it produces, off-grid solar is used more as a case study to illuminate broader themes of international development practice, namely its use of technology and the market to achieve its goals, than to offer suggestions as to how this particular type of technology might be better or faster disseminated. Other literatures are drawn on in later chapters such as work in discard studies (chapters 4, 5 and 6).

Literature review: Fixing development devices

Electricity is not the only type of infrastructure with which international development has concerned itself. Development practice has also focused on the absence, establishment and performance of infrastructures for health, education and water. Over time those concerns, like with electricity, have shifted in form from large-scale construction projects often involving national or local governments (e.g. electrification) to small-scale products distributed through market models (e.g. energy access). In the period following the Second World War foreign governments led efforts to support 'Third World' countries through the provision of technical solutions to address a perceived lack or insufficiency of infrastructures for health, education, water and other services. In recent decades, the design and dissemination of technologies for development has increasingly been conducted by private actors rather than the public institutions which dominated earlier development practice. Anthropologist Stephen J. Collier and colleagues describe this trajectory in the introduction to a special issue of Limn Magazine on 'Little Development Devices / Humanitarian Goods' (Collier et al., 2017) [9]. Development devices – a small scale product disseminated by private actors to serve as infrastructure - they write, emerged from the various critiques of earlier development practice that prioritised large construction projects and national transformation programmes. The off-grid solar product is an example of such a device.

Because development devices are being deployed in the place of previous forms of infrastructure, this section of the introduction looks at whether one of them, the off-grid solar product, adheres to identified features of infrastructure in the literature. Recent studies of infrastructure in the social sciences have stressed that it can take non-material forms, is locally-activated and propends to breakdown (Star, 2002; Elyachar, 2010; Larkin, 2013). While existing work on development devices. and their close relation, humanitarian goods,[10] has discussed the role of the market (a non-material form) in their delivery (Cross and Street, 2009; Dolan, 2012) and observed interactions with local populations and economies (locally-activated nature: Huang, 2017), little has been said so far about their breakdown. This section (and the thesis at large) then brings discussions of breakdown,

[9] Collier et al's trajectory matches that detailed by Escobar (1995). For Escobar, development came to centre, in the later twentieth century, on a need to find new markets for goods, the fear of communism and faith in science and technology. The first and last of these have been integral to the rise of the development device.

[10] Humanitarian goods are similar to development devices. The main difference is that they are predominantly used in disaster or emergency settings.

and responses to breakdown such as repair, to the emerging body of literature across social anthropology and cultural geography on development devices. The section ends with a brief mention of existing empirical studies of waste management for off-grid solar products – a small body of work to which this thesis also adds.

In the form of goods such as toilet bags (Redfield, 2012), water filters (Redfield, 2016) and rapid diagnostic tests for malaria (Street, 2017), development devices are presented as modern, dynamic and innovative solutions to problems of sanitation, water and health that more centralised or capital-intensive interventions have failed to address. They are designed to work in low- or off-grid settings: typically areas without connections to mains electricity or water services and often at a distance from tarmacked roads. The off-grid solar industry uses this discourse of previous failure and absence to create the appearance of an empty zone into which it can insert itself without need to integrate with pre-existing local economies and networks.

In spite of discursive efforts by development actors however the empty zone does not exist. People living in rural regions of the Global South still have access to forms of energy before the arrival of off-grid solar products. Diesel generators, kerosene lanterns or charcoal are widely available yet they are widely rejected by environmentally-minded, Western-led development efforts as old or dirty forms of energy. The connectivity to global supply chains that the presence of these 'traditional' energy sources proves is generally also neglected by the development community; it is inconvenient to their narrative of need. This construction of emptiness has been recognized by development scholars such as Escobar (1995) and Ferguson (1994) as well as those working in the area of discard studies. Millington and Lawhon, for example, write that areas of India are

> marked not by an absence of organisation or infrastructure but rather different modes of organizing the socio-materialities of collective life. (1046: Millington and Lawhon, 2018)

It is, Millington and Lawhon argue, in the contemporary context of increased population density and new goods and services that pre-existing practices are made to appear problematic, in need of correction. To which, in this case, development devices have been described and marketed as 'standalone', 'decentralised', even 'democratised' *solutions*. It is a language that implies an essence or independence of the object. Rather than seeing development devices as parts of assemblages their advocates grant them a stability and power to exist and perform as objects in isolation.

The size of development devices facilitates this understanding of them as discrete entities. Being small and portable has also made development devices amenable to market-based approaches for their delivery, allowing them to be distributed and sold like other consumer goods. Remote, mobile-enabled payment systems that can be managed at a distance further the illusion of these goods as free from the bureaucratic ties that infrastructure has historically implied. While this may be true in a material sense - the off-grid solar product does not require the underground or over ground cables that characterise a grid system, the products' journey to those remote, isolated areas of use relies upon various other connections. The off-grid solar product may be 'off-' in relation to the mains electricity grid but it is very much 'on-' the market that makes, transports, promotes and sells the products. These alternative, non-material, connections are supported by the work of sociologists Susan Leigh Star and Karen Ruhleder on ICT infrastructures. In a study of the Worm Community System - a collaborative piece of software for geneticists, they find that as decentralised technologies are used more and more across ever wider geographical distances the need for alternative forms of control emerges, such as common standards and categories (3: Star and Ruhleder, 1996). Quality standards have been a key part of the off-grid solar industry since they were introduced by a World Bank programme in 2008. More recently social impact metrics, for the benefit of funders and investors, have come to connect the products to other things in other ways as well.

An advocate of development devices may think that if well-designed and well-made it will work anywhere. But once development devices reach the off-grid area of their intended use they encounter the "local, customized, intimate and flexible use" that Star and Ruhleder also identify (3: Star and Ruhleder, 1996). In attempts to counter this the off-grid solar industry has responded with product quality standards and social impact metrics that frame appropriate usage.[11] While this standardisation of products and market categories seeks to foster market growth and facilitate business, local realities often complicate the picture. Development practitioner and journalist Maggie Black for instance writes:

> Some kinds of gadget, medicine, or piece of kit may have wide-scale application. But true development is about people, and social beings do not function mechanistically. (8: Black, 2007)

[11] These standards and metrics are discussed in detail in Chapter 3.

So while standards may seek to establish control and consistency, the embedding of infrastructure means that it actually

> emerges as a floating bricolage of half-fulfilled goals, continually mutating into new aims and new truths about the world. (342: Trovalla and Trovalla, 2015)

The continual negotiation of infrastructure (local activation) identified by cultural anthropologists Ulrika and Eric Trovalla in Nigeria also fits with the work of development scholar Ananya Roy who suggests that the merging of global markets with local conditions of poverty is "both complex and fragile" and "thus always under construction, never guaranteed." (106: Roy, 2012).

What is guaranteed in the life of an infrastructure is that it will break down. Often this will be the result of that outside imposition interacting with local realities. The inevitability of breakdown has been repeatedly emphasised by scholars of infrastructure (see Larkin, 2013) but has not been much explored in the nascent collection of work focused on development devices. Older work from Madeleine Akrich, however, encountered this during projects by the French government to introduce photo-electric lighting kits to countries in West Africa (Akrich, 1992), as did Marianne de Laet and Annemarie Mol in their study of the bush pump in Zimbabwe (Laet and Mol, 2000). While Akrich finds a disconnect between the French government designs and the situation in West Africa as causing the projects (and solar kits) to fail, de Laet and Mol argue that the fluidity of the water pump (its adaptable, flexible and responsive design) allowed for breakdowns to be continually responded to. They write:

> There are, to be sure, limits to the Bush Pump's flexibility and elasticity. There are points where nothing works, everything fails. But before such dead ends are reached – *if* they are reached at all – many varied things may happen to a Zimbabwe Bush Pump. As indeed they do. (248: Laet and Mol, 2000).

One of the "varied things" that can happen is repair. Writing of less fluid, and so less successful infrastructures in Nigeria, anthropologist Brian Larkin suggests that:

> The poor condition of infrastructure and the ubiquity of breakdown bring about their corollary: repair as a cultural mode of existence for technology. (235: Larkin, 2008)

It is a corollary that has garnered increasing amounts of attention in recent years as researchers recognise that breakdown is not an exceptional state but, for many technologies in many parts of the world, a regular occurrence that people contend with almost daily. Taking breakdown as a starting point, repair studies, a growing body of scholarship across anthropology, sociology and science and technology studies, claims that

> approaching infrastructure from the standpoint of repair highlights actors, sites, and moments that have been absented or silenced by stories of design and origination, (Jackson, 2015)

This thesis brings the approach of "broken world thinking" advocated by prominent repair scholar Steve Jackson (2013) to bear on development devices. Broken world thinking involves starting not from the design nor the dissemination of technology but from breakdown. Product design and dissemination through the market are addressed in the thesis (in Chapter 2) but predominantly in relation to their ability to shape breakdown and the later responses to it.

Aside from this relevant thematic literature on infrastructure, markets and repair there have been a small number of publications exploring the actual case at hand: the end-of-life, disposal and waste management of off-grid solar products (Pepinster, 2012; Batteiger, 2015; Turing, 2015; Verhoef, 2016; Cervantes-Barrón, 2016). This thesis then is not the first piece of academic research to look at this topic. What sets this thesis apart is not only its depth –it is the first doctoral study to explore such question. Nor its geographical focus – it is the first to focus on Kenya alone. Nor its attention to the actual breakdown of products – rather than just responses to breakdown. But its concern less with prescribing practical future solutions and more in understanding current responses. Rather than seeking to solve the 'problem' of the waste that off-grid solar products can become this thesis explores what our understanding and approach to the problem tells us about the thinking and philosophy involved in contemporary development practice. Instead of keeping the case study of waste within the off-grid solar industry this thesis seeks to attach it to broader questions about how development is practiced, how infrastructure is experienced, how markets shape that experience and how breakdowns in infrastructure are dealt with.

Research questions

The work of Cross (2013; 2017), Redfield (2012; 2016; 2017), Street (2017) and others points to a trend within international development to deploy technologies through 'the market' in order to improve the provision of infrastructure. If forecasts (19: Dalberg Advisors and Lighting Global, 2018) are correct, the case of solar technologies looks likely to continue to be a very prominent example of the trend. Given the centrality of breakdown to many scholars' understandings of infrastructure this thesis looks at the breakdown of off-grid solar products to explore how, if at all, these development devices are changing (experiences of) infrastructure in rural areas of the Global South. At a broader level the thesis also asks:

> What can breakdown and responses to breakdown of off-grid solar products, distributed through market approaches, tell us about development practice today?

This overarching research question is separated in to three sub-questions that concentrate on the market, breakdown and responses to breakdown respectively. The first sub-question, addressed in Part I asks *How does the market distribute off-grid solar products?* Existing work on the sociology and anthropology of markets shows that market devices such as quality standards are vital for the functioning of markets and that they are co-constitutive of consumers and products (Callon, Méadel and Rabeharisoa, 2002; Busch and Tanaka, 1996). This thesis builds on this by extending the implications of that co-constitution in to places and processes *after* consumption such as breakdown, repair and disposal.

The second sub-question, also addressed in Part I, moves more explicitly to the places and processes post-consumption to ask: *How, where, when and why does breakdown occur?* Existing work in repair and discard studies focuses on responses to or delaying breakdown (Jackson et al., 2014: Rosner, 2014) and deals less with what causes or contributes to breakdown in the first place. This thesis builds on that by focusing in some detail on what creates the need for a repair or a disposal in the first place.

The third sub-question, answered in Part II, turns to repair and disposal asking: *What happens in response to breakdown?* Existing work in repair studies has covered settings from USA (Rosner and Ames, 2014) to Bangladesh (Jackson et al., 2014) and things from cars (Dant, 2010) to bodies (Forlano, 2017). The thesis provides a new empirical case of off-grid solar products and adds in particular to understandings of repair in African

societies complementing Lara Houston's work in Uganda (2013) and Jackson et al.'s study in Namibia (2012).

The next section discusses the methods by which answers to these questions were researched.

Methodology: Following a broken thing

> Because the basic object of infrastructure is so diverse and can be analyzed in so many different ways, the choice of methodology is a theoretical question. (338: Larkin, 2013)

Understanding the infrastructural object of the off-grid solar product as an assemblage required a methodology that could somehow capture the various relationships, actors, and locations that constitute the assemblage. Answering the research questions laid out above needed a methodology that could interrogate the past, the present, points of sale, sites of use and places post-consumption. In other words, the methodology needed to be both multi-method and multi-sited. The methodology adopted, and described in this section, is known as following the thing.

In 2004, cultural geographer Ian Cook, wrote a paper called 'Follow the thing: papaya' (Cook, 2004). In it Cook offers a series of vignettes of different parts of the global papaya supply chain from farmers in Jamaica to consumers in the UK. His purpose was to make visible connections between distant and disparate groups in order to ask questions of the narrow stories of commodities we are often presented. Although the papaya is a thing, Cook's research exposes its wider assemblage of marketing, manufacture, labour and livelihood.

Since 2004 others have followed Cook's approach of applying a multi-sited ethnography (Marcus, 1995) to make visible assemblages of other things such as t-shirts (Rivoli, 2014), hot pepper sauce (Cook and Harrison, 2007) and flip-flops (Knowles, 2014). Yet these things have largely been followed from production in the Global South to consumption in the Global North, and discussion of what comes after consumption has been rare. Another geographer, Nicky Gregson, writes:

> 'follow the thing' research needs to also attend to flows 'down' the value chain, from developed to less-developed worlds, and to things that are either coming apart or being disassembled. … Paying attention to the back-end of the value chain

> shows that things are but temporary configurations of material. At best partially stable, things are argued to be endlessly being assembled, always becoming something else somewhere else. (846: Gregson et al., 2010)

Alison Hulme (geographer and follower of things) also calls on researchers to follow "what happens when things fall apart" (159: Hulme, 2017). Hulme advocates for particular attention to "the gaps", "collateral damage" and "micro-catastrophes" at each part of the chain (159: Hulme, 2017). Such attention is precisely what is given in this thesis. Where though does this following happen?

The off-grid solar products that are the subject of this thesis are conceived and designed in Europe or North America (the North) before manufacture in China and Malaysia and on to be consumed in South Asia and sub-Saharan Africa (the South).[12] The metals and minerals they contain come from Central and Southern Africa and South America while some of the parts and materials of products later move to Europe, India and China for recycling. However due to considerations of time, finances, language and access, the following, and so the multiple sites, in the research for this thesis have been largely within one country: Kenya. Although some research by way of participant and non-participant observation was carried out in Dubai and Hong Kong during and after industry gatherings in those cities.

Kenya was chosen as a case study because it has received the most attention from the off-grid solar industry thus far with most companies and organisations having regional offices in the country, and, with the highest sales figures it is the biggest market for off-grid solar products in sub-Saharan Africa (17: Dalberg Advisors and Lighting Global, 2018). The size and age of the market in Kenya meant there would be more likelihood in the research of coming across products that had broken down and users, repairmen, retailers, and other individuals who had witnessed, experienced or taken part in breakdown. There is also an established tradition within development studies, largely inherited from anthropology, to concentrate one's research in one location e.g. Escobar (1995) in Colombia, Mosse (2005) in India and Ferguson (1994) in Lesotho. This thesis then is offered as ethnography of development in that vein. It does not seek to make claims beyond the Kenyan context but

[12] There has been an important amount of Chinese investment in infrastructure in African countries in recent years that is less concerned with development devices and more with large scale road and rail projects. This activity is not discussed in this thesis. China does however also play a role in the story of off-grid solar products, as most of them are manufactured there. This features in chapters 1 and 2.

rather offer empirical evidence of how development operates at the local level that then allows for discussion of development in an abstract sense.

A key early step in the research was to sketch out the solar assemblage, its agents, relations and the abstract machine, within Kenya's borders. The one group that would clearly be relevant from the outset was users, the group who consume and so where post-consumption could be seen as beginning. A survey of users helped establish some of the other actors and locations that would be relevant. Once those locations were established, observation and interview were then used in conjunction with each other to see the assemblage in action in those locations and to hear how the actors within them understand their position, role and actions relative to others.

The next sections discuss the three main methods adopted: survey, observation and interview, explaining *how* and *why* they were used in this research. Further reflections on method are found throughout the thesis signalled by three asterisks (***) in a paragraph break. These paragraphs stem from the view that the method, the data it produces, and the researcher themselves are inseparable. By interspersing them through the thesis the reader is invited to reflect, as the author has done, on the close relationship between method, data and researcher.

Survey

Off-grid solar products have an advertised lifespan of up to five years (e.g. SunnyMoney, 2018) and some even over 5 years (see d.light, 2018).[13] Assuming for the moment that these are accurate, there was a small risk that during a year and a half of field research, I would not encounter any users who had experienced breakdown nor come across any broken down product. This would be a problem if my following was to begin and move forward from breakdown. To account for this, I needed a method that could cover a longer time period, a larger area and a bigger number of users (and so products) in order to maximise the chance of encountering breakdown and broken down products. It is for these reasons that I chose to run a longitudinal survey of users.

A telephone survey, conducted with 3 research assistants, made it possible to collect data from a wider area (9 counties) and sample size (262 people with at least 730

[13] Product lifespans are often shorter. This discrepancy is discussed in greater detail in Chapter 3 regarding different types of breakdown.

products[14]) than would have been possible to cover in-person myself. The survey also extended back in time to include products purchased in 2013. The survey was conducted in partnership with SolarAid – a UK-based charity.[15] The respondents, were all customers of SunnyMoney - a social enterprise that is owned by SolarAid and operates in several African countries. The respondents, called first in May 2015 and again in April and May 2016, were asked about their experiences with any electronic and electrical appliances at home (including their solar products): had they ever had any difficulties with them, if so, what had they done and what would they do should a problem occur in the future. The survey was useful then in answering the second sub-set of research questions around understandings of breakdown as well as the third set focused on responses and reactions to breakdown. As a result, the survey data predominantly features in chapters 3 to 6.

In May 2015 SolarAid's Research and Impact division employed teams of research assistants in the multiple countries where they operated. These teams were regularly tasked with conducting surveys to evaluate and support the charity's operations. Survey tools were generally written in English by management in London and then translated by the local (in-country) research teams. Results were supposed to be first recorded on paper at the point of collection and then typed up into an Excel database (where the categories were in English) afterwards.

By May 2016 SolarAid had closed down its Research and Impact operation and so for the follow-up survey I had to hire the three research assistants: Getrude, Juliet and Lilian independently.[16] With much improved Swahili and being based in Kenya by this point I was able to work directly with Getrude, Juliet and Lilian to write a set of questions in Swahili straight away. However, during the surveying itself I observed that entries were actually typed directly in to the Excel (and so never on paper) and perhaps expanded on

[14] The actual figure is unknown because we only knew the products bought from SunnyMoney. During home visits I learnt that users had often purchased other products through other channels as well.

[15] SolarAid partly funded this PhD through a collaborative scholarship with the UK Economic and Social Research Council (ESRC). This relationship with SolarAid manifested itself in three ways beyond financial support: firstly, I was given access to the SolarAid research teams in order to conduct the survey, secondly I was able to sit as an observer on the Sustainability Working Group at the Global Off-Grid Lighting Association (GOGLA) and thirdly, I had periodic conversations about the direction of the project with the now-former director of research and impact at SolarAid, Kat Harrison. Ahead of launching the survey I also spent one month on secondment at SolarAid's London office from mid-April to mid-May 2015 in order to familiarise myself with their survey methodology and research set-up.

[16] SolarAid underwent some restructuring in late 2015 that saw them close down their research and evaluation operations both in London and in their countries of operation.

(again in Excel) after the call. This meant that the precise wording of the survey tool as translated (2015) or written directly in Swahili (2016) was less important as the research assistants used the English-language Excel sheet to guide or structure the calls. Similarly, the calls, like many conversations in Kenya today moved through multiple languages: Swahili, English and, where the respondent and research assistant shared a third language, in this one too. These observations led me to decide not to quote the responses directly in this thesis, as SolarAid would do in their publications, but rather to use the content as illustrative of practices. I also tried not to read too much in to the phrasing or expression, having seen first-hand, and experienced myself during the handful of calls that I conducted, the difficulty of capturing wording accurately.

Users were all asked whether or not they consented to their names being used. They had also given their consent at the point of purchase to be contacted in the future by SolarAid, including for the purposes of research. However, there remained an ethical concern in that they had no prior warning of *when* these calls might occur, nor of what the topic of them might be. This meant that some customers were not able or willing to talk at that particular moment (on a weekday in working hours). The sample then, from the database of SunnyMoney customers, reflects those who answered their phone, the number of which was determined by how many Lilian, Juliet and Getrude could speak to in a two-week period, working more or less full-time. If customers did not answer a first time the research assistants would try again over the course of a day but the next day would start again from a later point in the Excel document.

Respondents received 100 Kenyan Shillings (approximately $1) compensation for their time after the second call in 2016. We did not tell respondents this in advance, based on consultation with the research assistants, in order to minimise the possibility of respondents being overly positive or altering their responses to those they thought we wanted to hear. Although given the commercial nature of their relationship to SunnyMoney this risk remained regardless. Unfortunately, because not all of those spoken to in 2015 answered the calls in 2016 not all respondents received their compensation.

At the end of the follow-up data collection in 2016, I complemented the phone calls with visits to a small number of users at their homes in Bungoma County on the border with Uganda. Getrude, one of the three SolarAid-trained research assistants, told me in a de-briefing interview that this was “a doubly good thing” because over the phone you cannot always tell if a respondent is happy or distracted nor see what she called their “unspoken

suggestions". "The observation bit is completely lost" she said.[17] This is similar to Malinowski, a pioneer of the ethnographic method, who, although an advocate of survey work as "an excellent skeleton" in the early stages of an ethnography stressed that it

> must be supplemented by the observation of the manner in which a given custom is carried out (17: Malinowski, 1964)

Ethnographers need, Malinowski maintained, to watch people's behaviours and be attuned to exceptions to that behaviour or those customs. The survey also acted then as a preliminary method informing later interviews and observations, helping direct where to go and who to speak to for the subsequent following. The next section discusses how the observational method was used in this research.

Observation

Surveys are relatively common in the off-grid solar industry. NGOs, development institutions, impact investors and manufacturers all use them (SolarAid, 2014b; SNV, 2012; Rom et al., 2017; M-Kopa, 2017) as do academics studying the industry (Gustavsson and Ellegård, 2004; Obeng et al., 2008). Practitioners also use the method. During interviews at the Kenya Industrial Research and Development Initiative (KIRDI) and the Kenya Renewable Energy Association (KEREA), for instance, I was told of recently completed and ongoing surveys at the respective organisations. The method however is less common in the studies of markets more generally conducted by economic sociologists and anthropologists. Nor are surveys common in studies of infrastructure or repair. Instead, these literatures draw more from interview and observational methods. Star for instance advocates for the use and value of observation in studying infrastructure (Star, 2002), while economic sociologist Mitchel Abolafia argues for the adoption of observation in studying markets, despite the difficulties of gaining access to what can be quite elite spaces (83: Abolafia, 1998). Observation is also a common method in repair studies (Houston, 2013; Jackson et al., 2014; Rosner, 2014). Wanting to engage with these literatures the method was adopted in this study as well.

[17] I interviewed each of the research assistants in order to better understand their experiences and qualifications and so explore what bearing they in themselves might have had on the findings of the survey. I conducted these interviews in May 2016, at the end of the survey data collection.

In addition to visiting some of the survey respondents at home in Bungoma, observations were conducted with repairmen, technicians and waste collectors to inform the third research question regarding responses to breakdown. These were predominantly in Bomet, a town in the south of the Rift Valley and in Nairobi, the capital, but also involved one day in Kitale, a town on the border with Uganda in the west, and a day in Mombasa, the country's main port and second city. In Bomet this was more participant-observation as I positioned myself for three months as an apprentice repairman in one of the town's independent repair clinics. The purpose of this was to learn how a small repair shop, which are common across Kenya, operates and in particular how the newer (relative to other electronic and electrical appliances) off-grid solar products were fitting in to this existing repair economy. In Nairobi, Kitale and Mombasa, much shorter visits and the fact that these observations were in company settings made the observations more of a non-participant form with technicians describing and demonstrating to me more consciously their daily routines. These observations complemented information I had already gathered from interviews (see below) with representatives of those companies. Observations with waste collectors (in Bomet and Nairobi) were as a participant but, being keen to maximise the one days I could spend with them, the observations involved me probing the collectors for explanations about their work and so were more intervening than typical participant observation. Observations were also carried out at industry gatherings in Dubai, United Arab Emirates (UAE) and Hong Kong in order to answer the first research question about the market's development and contemporary form. Observations, both participant and non-participant, contribute to all three sets of research questions and so the data collected through observation is found throughout the thesis.

Observations helped me to see the assemblage in-action. In interviews or surveys while actors may speak of others just one actor is being engaged with at any one time. In observation however I could watch how repairmen interacted with the solar products and how they engaged with users. I could observe how technicians related to company processes and market institutions through their work. Observation also has empirical value in watching and learning how things get fixed as well as how and where things are disposed of. At times this offered visual information to compare and contrast with how the same individuals spoke about these processes or, in the company settings, how their, often senior, managers explained processes to me in interviews.

Languages varied across these observational settings. In the independent repair setting the repairmen and I spoke Swahili with each other as was the case for the observations with waste collectors. In the company repair settings however conversations were more often in English with some occasional Swahili. I recorded observations by making notes to myself on a mobile phone that were later typed up on a laptop in the evenings and on Sundays (when the repair clinics, companies and waste collections were not operating).[18] These notes would be in short-hand and typically describe a series of events. Occasionally, when struck by a particular phrase, I would record quotes verbatim or questions to myself to contemplate at a later point in time. I also took photographs during observations. This was perhaps the more conspicuous form of data collection as I was using a digital camera to do so and its use, at arm's length from the body, is more visible than the mobile phone close to one's chest.

Those I observed and their work and places of work that I photographed all gave verbal consent to use what I saw and recorded. I thanked the two repairmen to whom I was an apprentice for three months with some parts for their clinic which I took to them from Nairobi. Those whom I observed for shorter periods received photo portraits as gifts (if requested) or lunch and/or other refreshments. None of this compensation was agreed in advance and so informants did not agree to participate for their personal gain but through, what appeared to me, as generosity. Having said that, my status as a white outsider and the associations of expertise and authority that that can bring (Kothari, 2006) may have led some informants to expect or anticipate some benefit from their interaction with me. That they did not benefit, beyond the token gifts, is an unfortunate, if not uncommon, effect of the observation method.

The next section discusses the third method used in this research, interviews.

Interview

Observation in repair clinics, company premises and of waste collection rounds however only gave me access to products that had already broken down. These observations then

[18] I initially recorded observations on pen and paper but this seemed to attract more attention from informants who were interested to know what I was writing. Contrary to my original thoughts it was less conspicuous to have my smartphone out and make notes on it as the repairmen were constantly using their own phones to light up products, receive calls from customers, contact friends or bet on the day's football matches.

were more useful for the third research question (responses to breakdown) than the second (how breakdown happens). Originally I had the idea to live off-grid myself while conducting fieldwork. I wanted to live with a family using a solar home system in order to observe on a daily basis how the product was used and increase the chance of witnessing first-hand how breakdown is dealt with. However, on arrival in Bomet this proved difficult. I also began to reflect more on the practicalities of living off-grid which would have made note-keeping (on a laptop) difficult – laptops cannot be charged off the current range of SHSs on the market. Living with a family I would also have been a much greater burden, for a longer period of time than as a one-off or occasional visitor. And there was still no guarantee that I would witness breakdown first-hand. Another method was needed then to answer the second research question about breakdown. To fully answer the first research question, particularly its interest in the historical development of the market, I needed a similarly retrospective method to capture events that had already passed before I came to observe them. This need to hear explanations and stories of past events was a key reason to use interviews in the research.

Semi-structured interviews were conducted with users, company representatives (from both manufacturers and distributors), repairmen, technicians, financial partners, government employees and other individuals involved in or relevant to the industry. Interviewees were accessed through cold-calling (in-person, over the phone or by email), through snowballing (from previous interviewees, existing contacts or observations) as well as networking (at relevant events and conferences). The community was relatively small and so easily navigable at the time. Some respondents had previously worked for other companies and organisations (as I had myself) while interviewees and I often realised we already had mutual contacts in one of the other companies or organisations. And on one occasion as I waited in an office reception before an interview I was passed by someone I knew leaving a meeting with the interviewee only to pass another mutual contact when I myself left the office an hour later. While generally successful in arranging interviews I sometimes faced problems. Interviewees in government departments or agencies were particularly unresponsive or difficult to arrange – I arrived at empty offices and voicemail services on numerous occasions. And similar to Gregson and colleagues in Bangladesh I sometimes had difficulty finding homes (of users) and challenges with the “rapid turnover” of changing phone numbers (851: Gregson et al., 2010).

Interviews mainly took place at the interviewee's place of work or a nearby café, hotel or restaurant, except for users where the visit to the home was integral to the conversation. Most interviews lasted around 40 minutes (although some home visits lasted a little longer). I prepared by creating a list of questions and topics in advance, like the checklist discussed by Crang and Cook (66: Crang and Cook, 2007). However, I tended to only refer back to this during the interview if a certain line of questioning reached an end or there was a lull in the conversation. Although most interviews were conducted in English, many were conducted in a mix of English and Swahili (with both the interviewee and I shifting between languages); the balance of the two languages varied according to the context. Most were recorded with an audio recorder unless an interviewee did not wish to be recorded (two occasions) or the setting was not appropriate (i.e. home visits where our conversation moved around and we interacted frequently with our surroundings which regularly included young children and free-roaming chickens). The order that the interviews were conducted in was largely determined by the availability of respondents. Earlier hopes to conduct them sequentially in groups, progressively focusing in on the product itself: government representatives followed by financiers followed by distributors and manufacturers, was abandoned and ultimately the groups became mixed up according to when particular individuals agreed to meet and speak with me.

Interviews focused on actual or anticipated cases of breakdown and response, in some instances interviewees would articulate an ideal scenario instead or in addition to the actual or anticipated ones. The intention behind the interviews was to clarify and expand on things I had seen in observation but could not ask about in the moment of observation itself. Interviews also allowed me to ask about those things I could not observe: i.e. the moment a breakdown manifests itself to the user or, in the case of government and company interviews, to understand the intended processes so as to compare them with the observed ones. Interviews, like observations, contributed to all three sets of research questions and so data collected through this method is found in each of the six chapters that follow.

The recordings of interviews were transcribed and, where practical (i.e. when the interviewee had the means to access, read and understand it), shared with the interviewee. When sending transcripts I sometimes asked follow-up questions; for introductions to other relevant individuals or to arrange an observation. This thesis document will also be shared with the same interviewees if they wish. The quotes taken from interviews that are used in

subsequent chapters of the thesis have at times been tidied up to make them easier to read. This mainly involved the removal of hesitations such as “um”, “ah” and “er” or repeated words. However, where the hesitation or repetition was seen as important to the meaning or message of the quote they have been left in. For interviews at home I took users a box of shortbread, explaining this was a typical snack in Scotland where I came from, some also received a printed photo of them or their children if they had asked me to take one. Company interviewees were not given any gifts as such, although I would buy their lunch or drink(s) if the interview was in a hotel or café.

This section on research methodology concludes with some reflections on consent, ethics and language.

Consent, ethics and language

The majority of interview, observation and survey responses in the following chapters are written in English. Where the information was originally expressed in Swahili, the translations are my own.[19] Swahili terms are used when part of company or project names or when I felt that translating would lose some sense of the meaning. All the responses are used with the permission of those that gave them, using their names if consent was given and their preferred title. If consent to use their names was not given then a generic term is used, such as a job title. Where permission was not given to use the job title, a yet more general description is used.

Consent was not secured from everyone however. There were cases of what could be called collateral observation. When working with repairmen, for example, I did not secure or seek consent of all customers who visited the repair clinic to factor in their visit and that interaction to my understanding of how the repair business operates. Similarly, in the company setting, where users (or owners) of products were not present, customers had not consented to me using their products and experiences in this study. However, in both these cases it was not practical to secure such consent, nor was it necessary for I have not used any identifying details in these cases. The same holds for colleagues of my main contacts in the company setting where their peripheral activities around us in the office,

[19] In addition to a year-long introductory Swahili course in Edinburgh from September 2014 to June 2015, I spent three months studying the language full time in Mombasa from August to October 2015. During the three months in Mombasa I lived with a local family and so was also speaking Swahili outside of lessons and self-study.

workshop or warehouse may feature or for observations of waste collection processes where waste producers did not know their waste was becoming part of this PhD project.

In cases where consent *was* secured I occasionally had some concerns about the participants' understanding of the research. When introducing my research topic to people for instance they would often ask if I was a physicist or an engineer presumably due to my stated interest in solar and technical activities. Others meanwhile did not necessarily understand the purpose of a PhD assuming that the fieldwork was some sort of market research – a precursor to launching my own solar, repair or waste business in the industry. Such possible misunderstandings are mitigated by the purposes to which their participation has been applied: to inform an academic thesis. Should I later launch a business in the industry, the time that has already passed since the data collection combined with the rapid pace at which the industry is moving and growing make any direct (negative) impact on those who misunderstood their participation in the project extremely unlikely.

One group particularly conspicuous in their absence from this research is children. For social science research this exclusion perhaps made approval of the university ethics board easier. However, children were often spoken about in interviews and conversations so not speaking to them does mean that I missed the views, opinions and perspectives of a key group. Their role is particularly prominent in chapters 2 to 6. The other groups I engaged with were relatively protected either by a salary or having agreed to give me their time voluntarily at a time that suited them. Although my presence may have slowed operations in the repair clinic or company setting, informants in both locations insisted I was welcome back at any time. These invitations could have been offered out of politeness or perhaps offer an indication that I was not always as disruptive as I felt at times.

In addition to field notes of my observations, interview transcripts and survey responses I also took photos and kept an infrequent research diary to record the more strategic, emotional and personal thoughts relating to the research journey. The research diary does not feature in the thesis but it is where decisions relating to the direction of the project were taken such as the altering of specific field sites and changing the relative amount of time spent in each of them (see below). The photos do feature in the thesis but are largely used for illustrative purposes, to accompany and enhance written description. They are not analysed as data *per se*.

The research process

The field research was conducted in four trips to Kenya totalling 17 months between October 2014 and September 2017.

The first trip, a ten-day scoping trip in October 2014, took in a series of meetings with solar manufacturers and distributors in Nairobi and Naivasha, a large town in the Rift Valley. The trip also involved introductory meetings with the SunnyMoney team and a day observing their sales operation in Kakamega, a county in the west of the country.

The second trip of three-months from August to October 2015 was spent in Mombasa learning Swahili at the Research Institute for Swahili Studies in Eastern Africa (RISSEA). I was originally planning to conduct fieldwork in the city and so outside of lessons, self-study and spending time with a host family, I made forays to Mombasa's main waste site, Kibarani, to some scrap merchants exporting from the port, and solar retailers in the town. However, for reasons of time, access (the port is, understandably, a highly protected area) and focus (the research shifted away from following waste flows, where Mombasa would have been key, to concentrate on repair for which the city is less unique) the city was later removed as a site in the research. I did return there however to observe the after-sales operations of a distributor in December 2016.

The third trip to conduct the main body of the fieldwork ran from January to December 2016. The year involved three months in Bomet County, a fortnight in Bungoma County, six months in Nairobi and one month moving around Central and Eastern Kenya. In Bomet the focus was the second and third research questions. I observed solar products in an independent repair clinic (fig. 0.3), then followed them back to the users' homes where interviews were conducted. In Bungoma County I visited more users at home (fig. 0.4) for follow-up interviews based on their responses to the telephone survey – these were also targeted towards the second and third research questions. The data gathering in Nairobi addressed all three research questions. There interviews were conducted with manufacturers, distributors, financial partners, industry and government representatives. Observations were also conducted with manufacturers, distributors (fig. 0.5) and waste management companies

Figure 0.3 Malo Malo, the independent repair clinic (left) and neighbouring businesses in Bomet (Author's image, March 2016)

Figure 0.4 A user demonstrating how they charge their solar product in Bungoma County (Author's image, May 2016)

Figure 0.5. The workbench in a workshop of a solar product distributor in Nairobi (Author's image, December 2016)

The original intention had been to return to Bomet at the end of the year and so one function of the Nairobi stint was to collect letters of support or recommendation from central offices and headquarters to facilitate access to their branches and representatives in Bomet. Individuals in Bomet had been reluctant to speak to me without direction from their superiors in the capital. However, some challenges of access and delays in arranging interviews and observations in Nairobi meant that the stint there was extended and the return to Bomet pushed back until the following year. Also, after having done the Nairobi interviews I became doubtful of what further information I would get by returning to speak to representatives at the local level.

Instead I finished the year with a month devoted to the first research question. I travelled around Central and Eastern Kenya conducting interviews with individuals who had been involved in the industry in the past or been part of it for a long time. I also visited historical sites of solar projects (fig. 0.6).

F**igure 0.6** A panel on the roof of a house in Murang'a County, installed as part of a World Bank project in the 1990s (Author's image, November 2016)

The fourth trip took place over six weeks in August and September 2017. The trip involved one month in Bomet, visits to Kitale and Kisumu to the west and some days in Nairobi. The return to Bomet mainly consisted of observing the rest of the town's repairmen at work and also following elements of the town's waste streams (fig. 0.7). The visit to Kitale was to speak with a manufacturer's representative there (fig. 0.8) while the visit to Kisumu was intended to learn about the personal background and training of one of the key informants, one of the repairmen worked with in Bomet in 2016. Finally the days in Nairobi included shadowing workers at an electronic waste management facility (fig. 0.9).

Figure 0.7 The day's collected waste being offloaded at the town dump in Bomet (Author's image, September 2017)

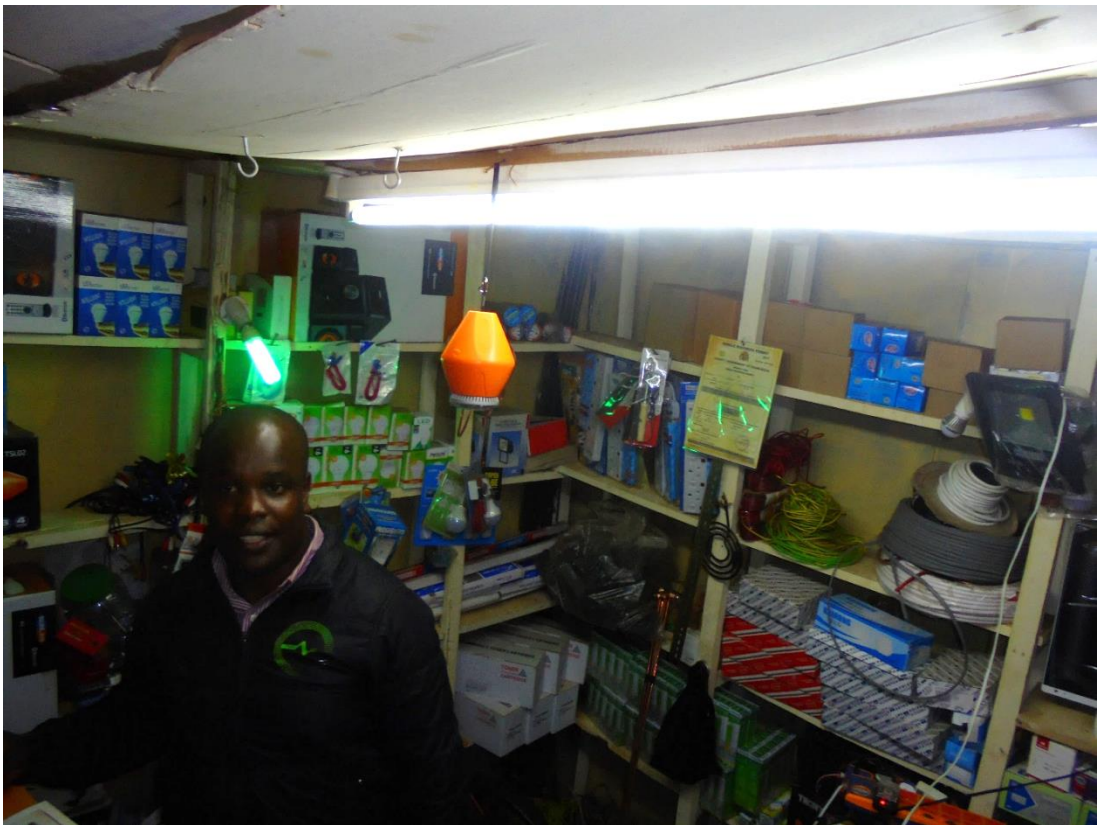

Figure 0.8 Henry the representative in Western Kenya for a solar manufacturer in his shop in Kitale (Author's image, August 2017)

Figure 0.9. Solar panels in storage at an electronic waste management centre in Nairobi (Author's image, September 2017)

During the course of this research the project had an external profile – its existence was known by outside actors and many were following its progress. SolarAid, for instance, put out a news item regarding the project (SolarAid, 2015b). And a Twitter profile (@declanrmurray) and a blog (solarandotherstories.wordpress.com) meant that others outside of Kenya were able to follow the project's progress, several of whom got in contact. Individuals from academia, journalism, industry and the non-profit sector all reached out to me at various points asking for information about how their operations would be affected or could be improved with regards to disposal and recycling – most of these requests were practical or utilitarian and less interested in the more conceptual contribution the research has to offer. While these interactions rarely led to new insights for me the very fact that interest was growing and continues to grow in this area was itself interesting and at times reminded me of the project's relevance and importance. These phone calls, meetings and email exchanges also gave me periodic opportunities to try and summarise or articulate the findings to individuals with varying levels of familiarity with the industry, questions of waste and repair or Kenya and sub-Saharan Africa. The profile of the project and my relationship

to an industry working group (via SolarAid) led me to attend and be invited to speak at several conferences and workshops over the four years as well – these, like the conversations with individuals gave me opportunities to reflect on my findings and influenced the direction of the project whilst also acting as sites for data collection by observation too. This professional contact also led to some consultancy work with one manufacturer (not involved in the thesis) and the possibility of more work in the future.

Outline of thesis

Part I of the thesis sets out the nature of the off-grid solar industry in Kenya today and also outlines the conceptual understanding of breakdown which the analysis in Part II builds on.

The first chapter revisits some of the earliest recorded photovoltaic (PV) installations in Kenya and speaks with the users, designers, and technicians of old, no longer shiny systems. Retracing a chronology of PV in Kenya from the early 1980s to now the chapter shows that the technology has got cheaper, smaller and reached more people. Where earlier projects were run by outside charities or NGOs today's installations, still led by outsiders, are delivered by social enterprises committed to the diffusion of technology through the market. The chapter argues that these trends have kept users outside of the technology and so reduced the need for, ability to, and interest in, repair. A focus on growth and market development has also neglected the material legacy of the technology over the last 40 years.

Starting at an industry conference in Dubai, Chapter 2, outlines the contemporary global off-grid solar market. The chapter describes two influential market devices: quality standards and impact metrics, that distinguish a certified market from a non-certified one. The second half of the chapter moves back to Kenya, first to capital Nairobi to see how the devices are used by certified market actors to push for favourable tax, import, and energy policies, and then to Bomet, the main fieldsite for this research. Here the main companies that are examined in the thesis are introduced and how their products are sold, distributed, and financed. Despite the work done, through market devices, to differentiate them, the two certified and non-certified markets are much closer at this level. The chapter argues that the effort invested in creating the market (through the standards and metrics) sidelines product repair and waste management.

Chapter 3 introduces the various types of breakdown that can occur within the solar assemblage. These can be breakdowns in design, manufacture, impact, use, water

damage, dust, dirt, fire, theft or a business decision. The chapter works with breakdown to show that functionality is not a determining factor in whether or not something is disposed. Breakdown moves a product in to a gap between consumption and disposal. It can be returned from this gap by repair or it can be moved on by acts of disposal. The chapter concludes that where breakdown is, who the product is with and what type of breakdown has occurred all shape the possible responses to it.

Part II of the thesis forms the basis of the empirical contribution. Over three chapters the broken down solar product is followed across three sites: the home, the independent repair clinic, and the company premises.[20] At home, the most common response to breakdown is to wait: the certified market is creating passive users who await further instruction rather than pursue their own repair or take it to the repair clinic. Where repairs *are* made Chapter 4 suggests that these are more often of oneself or one's routine (a repair of practice) than any material alteration (a repair of product). Material repairs are more common in repair clinics but as Chapter 5 demonstrates there are also limits here. Next to other household electronics the small, simple solar product does not promise much profit for repairmen,[21] nor are the necessary spare parts available and so they increasingly direct users towards company warranty processes instead. Repair is limited at the company premises too. Motivated by a concern for brand image and a minimum and consistent level of quality Chapter 6 shows how companies (and their partners) replace rather than repair products. Despite an emphasis on training and process, observations reveal that informality persists however and technicians work to repair out-of-warranty products or earn a side income. When repairs *are* done, similarities are found across the three locations. Through a process of trial-and-error people draw on previous experiences, cannibalise other objects and prioritise functionality over any aesthetic aim or benchmark. It is suggested that these commonalities are comparable to the idea of *bricolage* as articulated by Claude Lévi-Strauss (1994).

At each repair location (and in any act of bricolage) however, there is, as Houston found in her work with mobile phone repairmen in Uganda "that [which] cannot be tidied away" (55: Houston, 2017). And so chapters 4, 5, and 6 also describe the "material legacies

[20] Premises is the preferred collective term as company activities take place in offices, warehouses, and workshops. Furthermore, the work performed in each of these locations does not always correspond to preconceptions of the location's intended use (i.e. an office may include storage of stock normally found in a warehouse or repair activities more typically associated with a workshop) nor is the relationship between work and space consistent across companies.

[21] And they *are* all men.

and externalities" (55: Houston, 2017) found and produced in those respective locations. Although products are sometimes put down the toilet, into the ground, burnt in a fire, or sold as scrap at home, Chapter 4 describes how the majority are held on to. Broken down products are found waiting in Chapter 5 too. In the clinic, uncollected products either form the basis of the repairman's stock to facilitate future repairs or they are eventually disposed of by being sold on (to metal collectors) or fed in to the municipal wastestream. In cases of the latter objects are burnt at the side of the road or taken to landfill, if not first siphoned off by passers-by and playing children. Products returned to company offices, warehouses and workshops also wait. If not siphoned by security staff or employees of the waste company collecting them Chapter 6 explains how products can end up in one of Nairobi's landfill sites. Others are sent to manufacturing facilities in China to aid future product improvements or stored until collection by a recycling company.

The thesis concludes with a call for greater attention to repair within international development. Health, sanitation and cooking, where goods and technologies distributed through markets have also come to prominence in the fixing of problems of poverty (and climate change) are possible areas where this might be useful. The development project at its heart recognises the current state of the world as unacceptable, as broken. Too often however responses to that breakdown (through projects and increasingly products) do not work from what exists, as the *bricoleur* would do, but draw on new resources aiming for a permanent fix to the broken-ness. Learning from repair studies and 'broken-world thinking' (Jackson, 2013) perhaps a more successful approach to development might be to accept the inevitability of breakdown and work on continual repair rather than futile attempts to out-design or out-innovate the broken world.

Part I

Making and breaking products

Chapter One

Revisiting a history of solar photovoltaics in Kenya

A development technology

The first installation of solar panels in Kenya is thought to have taken place at some point in the late 1970s. Panels are believed to have been used to power telephone masts in rural areas (75: Byrne, 2009). Over the 40 years since, the solar assemblage has continually changed in form and grown in size. In terms of locations the technology has moved from being solely found in institutional settings to come to focus on individual households. Materially, systems have shifted from being built and assembled in-country to full manufacture in China. Application-wise the technology was used first for refrigeration then for running televisions then came a concentration on lighting before moving back up again in recent years to powering radios, mobile phones and televisions.[22] Delivery models have also moved: from being dominated by one-off projects towards being led by a vibrant market of specialist companies. And at the level of human resources early projects were driven by environmentalists committed to training Kenyans as technicians while their successors have committed more to a commercial approach where Kenyans perform the roles of sales agents.

One continuity of the solar assemblage underlying, and at times driving, these changes is the technology's continued proximity to international development. Solar PV in Kenya has been financially supported by international sources (from the Global North), advocated and spread by foreigners (often white and male) in the pursuit of other goals (particularly in health and the environment) on top of its contribution towards rural electrification. Such directionality and the dynamics of race, gender and power that it involves are of course not unique to solar but are found throughout development practice, and beyond. Existing histories of solar PV in Kenya however do not reflect adequately upon them.

[22] The latest moves in the industry are towards solar-powered water pumping, milling and irrigation (Kent and Pielli, 2018).

The most thorough accounts of PV development in Kenya are found in *From Space to Earth* by John Perlin (2002) and sections of Robert Byrne's doctoral thesis *Learning drivers: Rural electrification regime building in Kenya and Tanzania* (2009). Perlin, a trained physicist and vocal advocate for solar power, traverses the globe in his history of breakthroughs and firsts for solar power. It is an empirically rich text that tells, in his own words,

> the story of people who innovated, went against the grain, bucked authority, and risked it all to turn a mere scientific curiosity into a booming business. (xiv: Perlin, 2002)

Perlin does not however dwell on the overwhelming identity of those people as white men. Byrne, meanwhile, in a regionally and temporally more specific study seeks to answer why PV adoption is markedly different in Kenya and Tanzania. Approaching the question through the framework of 'strategic niche management' Byrne discusses the importance of social networks and institutions in the development of the technology and does make more of the role of pioneering Kenyans. But, like Perlin, Byrne makes no explicit comment on the race or gender dynamics of those networks and institutions.[23]

Perlin's and Byrne's narratives also trace a successful trajectory, as David Edgerton argues is common in histories of technology (Edgerton, 2008). Their forward narratives of diffusion, development and progress diverts attention from that which breaks down, does not work or is left behind. A timeline marked by new innovations and introductions is always shadowed by a timeline of less visible but more frequent moments of break down, decommissioning and disposal.

What makes the history in this chapter distinct from the work of Byrne and Perlin then is two things: one is its attempt to reflect on the gendered and racial origins of the technology, drawing out the consequences of these origins for the technology, its use and its users today. The other is its attention to the material legacy of previous projects, programmes and businesses.

The pioneering individuals behind the spread of PV in Kenya from the 1980s to now were able to be such by virtue of their race, gender, nationality and youth.[24] As white

[23] Although Byrne has since written on the gender dynamics of off-grid energy transitions in Kenya (Marshall et al., 2017), the issue is not directly addressed in his thesis.

[24] The reader should be aware that I am also a white man in my 20s and that I came to the topic of off-grid solar after having worked for a solar home system provider in Kenya and Uganda. In these

outsiders these were individuals who had easier access to resources and organisations than their Kenyan colleagues, friends and employees. They were also able to reach higher levels of study – in several cases pursuing Master's degrees in relevant subjects. These early dynamics of male, outsider dominance have continued until today where gender roles are such that it is largely men, especially outsiders, who implement solar technology and Kenyans, especially Kenyan women, who benefit from it.

Perlin's focus on technical legacies, each new iteration or application building on the last and Byrne's focus on social ones, how communities of individuals and organisations came to build a niche market, neglect the materiality of the technology's dissemination. Although often learning from previous efforts, each stage of PV's development in Kenya has neglected the material leftovers of what came before. Hardware has not been collected, re-used or re-purposed but, in addition to the programme structure and financing models it has been wholesale replaced. This chapter seeks to counter this neglect.

The chapter then draws attention to people left out (Kenyans, especially women) and things left over (waste materials). Its contribution to the overall argument of the thesis is to show that how the technology is designed and distributed and by whom shapes how it breaks down and what happens when it does so. Like development's inherited colonial origins (Kothari, 2005), the solar assemblage has inherited racial dimensions that shape whose expertise is valued and the roles that different groups are to play within the assemblage. Being an external technology delivered by white outsiders frames Kenyans as users of it, not its designers or repairers. Seen as an outside technology because it has been brought from outside by outsiders has also left Kenyan users with little understanding or knowledge of what to do with the technology when it breaks down. Despite the fact that some of the early pioneers were themselves *bricoleurs*; working from constrained personal budgets they used off-cuts of old panels and made other components from scratch, the dissemination of solar technology in Kenya has tended towards more of an *ingénieur*'s model. The ingénieur for Lévi-Strauss always tries to go beyond any limits they encounter (19: Lévi-Strauss, 1994); in the case of off-grid this has led to the wholesale introduction of materials, expertise, financial services, benefits and marketing to solve the question of energy access, rather than building upon existing or leftover skills and materials.

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respects, I am very much part of, and have benefited from, the structures embedded through the history described in this chapter.

In November 2016 I took a month-long trip to early and historically significant sites of solar PV installations. I used Perlin's authoritative history (2002) and Byrne's doctoral thesis (2009) as starting points from which to navigate. I moved to health centres, schools, businesses, banks and private homes across Eastern and Central Kenya tracking down panels, refrigerators, batteries and other components; and then speaking to the users and technicians of these older systems and projects.[25]

The chapter recounts this trip and traces the shifting shape of the assemblage chronologically. It begins with the experiments of the 1980s where local skills were valued and the space-age technology was brought to rural households. Next comes the project-focused 1990s when attention turned away from the social towards the technical with efforts to ensure quality through targeted manufacture. The 2000s were product-centred as the efficiency of components and scale manufacture in China made solar both portable and affordable. Since 2008 the 'bottom of the pyramid' approach has dominated with the arrival of companies and business models focused specifically on what is called 'last mile distribution'.[26] The chapter closes by suggesting that solar PV in Kenya has largely been implemented through what can be characterised as an ingénieur's approach where the technology, expertise and finance is brought in from outside and engagement with pre-existing resources, as bricolage might do, has been limited.

American equipment, expertise and finance

Byrne (2009) has shown contrary to earlier studies (Lorenzo, 1997; Nygaard, 2009) that the development of the private PV market in Kenya has benefited a lot from donor funding, most of it American. In the early 1980s the American influence on the solar assemblage however extended beyond finance to the equipment and expertise involved in projects too. This influence came with consequences. Donor funding meant that PV's applications were defined by American implementers and so were often tied to development goals such as

[25] Although Eastern and Central Kenya are historically important regions for solar PV in the country, the industry has come to focus more in recent years on the more heavily populated Rift Valley and Western regions.

[26] The bottom-of-the-pyramid, or BoP, is a term used to refer to the poorest people in the world. It was popularised by business scholars C.K. Prahalad and Stuart L. Hart in the early 2000s to denote those whose annual income is under $1,500 (Prahalad and Hart, 2002). Last mile distribution is a term borrowed from supply chain management that refers to the delivery of goods at services in remote, often rural areas and generally targets those at the bottom of the pyramid.

improving the quality of healthcare provision. High equipment costs meant this was delivered at an institutional level. Bringing equipment and expertise from the outside generally put Kenyans in the position of users. Being left out of the project design and implementation also left them *outside* the solar system. Users were not tasked with or trained in matters of installation, maintenance or repair. Not feeling nor having ownership over the solar systems was also disabling when it later came to the question of disposal of no longer functional equipment – users did not know what to do. Together these aspects contributed, as has been documented in development studies, to "whiteness and the west" being regarded as "symbols of authority, expertise and knowledge" (10: Kothari, 2006). The association of PV with white Americans contributed to a perception of them as symbols of modernity and progress (16: Kothari, 2006). This in turn made solar technology a target of theft – a theme that runs through to the present day. That the first American engineers were men is also significant, as will become clear later in the chapter. But first, an anecdote.

Steve moved to Ikutha in 1992, when his mum was posted to the area by Kenya Wildlife Service (KWS). Whilst only six years old at the time, Steve remembers going for check-ups at the Ikutha Health Centre where he is now the director. He also remembers the solar panels. Although bemused at why I was interested in something so old (the system was installed in 1983), Steve walked me nonetheless from his office to where the panels used to be. Passing under two wind-ripped, sun-faded USAID shelters we re-emerged in to the sun and Steve pointed to a white square in the ground. Steve said this concrete slab was part of the fence that surrounded the array. When the system stopped working (ca. 1999), all of its parts remained in place, for a time, he told me. But then some of the panels were stolen, at which point the others were moved inside for safe-keeping. Steve took me to the Drug Store to show me where these remaining panels were being kept. Some parts of the system had not been moved however; the control box, light fittings, switches and wires were all still in place. Steve pointed these out to me as we moved from building to building, retracing the movements of the system centrepiece – the refrigerator – from its original position in the Laboratory towards the Store where it was resting in 2016 (fig. 1.1).

Figure 1.1 The original vaccine refrigerator in the Store with USAID-branded boxes of fortified food on top and to the side (Author's image, November 2016)

I asked Steve why all this stuff; the panels, the fittings, the refrigerator, was still there. He said it was because it belonged to the Ministry of Health - he or his team could not do anything with it. But when the Ministry of Health returned in 2015 to install a new solar-powered refrigerator (fig. 1.2) in the same building where the old one had been (now the Ante-Natal Check-up unit), they did not take the old one with them, nor did they offer Steve and his team any direction on what to do with it.[27] Ownership and responsibility are themes that are re-visited in chapters 4 and 6 as they influence user and company responses to breakdown.

[27] Although the Health Centre was connected to the grid in 2011 Steve estimated they have power-cuts about two or three times a week sometimes lasting for up to 12 hours and so still have a need for solar-powered refrigeration.

Figure 1.2 The new refrigerator with USAID sticker in the Ante-Natal Check-up room (Author's image, November 2016)

Leaving Steve to get on with his day's work: taking chilled vaccines (from the new, again USAID-funded, fridge) to Mukuanima, a remote market centre on the edge of the Tsavo East National Park, I headed down the road towards the Police Station to see if anyone there remembered, or had a record of, the panel theft that Steve had told me about. Theft remains a concern for contemporary users of solar PV. It is a theme that will be revisited in Chapter 3 as a cause of system breakdown.

The installation at the Ikutha Medical Centre was part of a World Health Organisation (WHO) project called the Expanded Programme on Immunisation (EPI).[28] The equipment I saw in Ikutha and Kibwezi, the second of two Kenyan sites in the programme (Roberts and Ratajczak, 1989), 48km kilometres downhill from Ikutha, was installed by employees of the United States' National Aeronautics and Space Administration (NASA). NASA had been an early adopter of PV in the 1960s, recognising it as the safest, most

[28] The programme, launched in 1974, aimed to vaccinate children around the world. It targeted in particular diphtheria, whooping cough, tetanus, measles, poliomyelitis and tuberculosis (WHO, 2018).

reliable (if expensive) source of power for satellites and space probes (50: Perlin, 2002). Space was, in many ways, the off-grid region of the industrialised world. Africa, however, particularly south of the Sahara remained for the most part off-grid. And so having gained experience of the technology in space NASA engineers were called on to advise for projects on Earth like EPI. Although NASA provided the expertise for the EPI installations, the actual materials of the refrigerator systems were supplied by an American company called Solarex. The finances for the project meanwhile came from yet another American body, the United States Agency for International Development (USAID). In order to photograph the original EPI refrigerator (fig. 1.1) Steve and I had to move several USAID branded boxes of food supplements: "We get so much from USAID" he said as we moved the boxes to one side.

The examples of Ikutha and Kibwezi are not anomalies in either their American connections or development applications. Most early PV installations were oriented towards community-level facilities like health centres or water pumps – both government and charity-run. The clinic in Kibwezi was run by a charity called the African Medical Research Foundation (AMREF).[29] If not directly connected to their work (i.e. AMREF's need for vaccine refrigeration in Kibwezi) non-governmental organisations (NGOs) and Christian missions were, due to high costs, the only feasible clients for solar in the late 1970s and early 1980s. These wealthier groups would buy systems to power their offices or living quarters (131: Perlin, 2002). Safari camps, such as those in Tsavo East that borders Ikutha or Chyulu Hills across the railway from Kibwezi, were another group of PV customers at the time (see fig. 1.3).

[29] The clinic, now hospital, at Kibwezi was run by AMREF until 2015 when it was taken over by the Ministry of Health.

Figure 1.3 A photo of the Tsavo River gate to Tsavo West National Park shows one rotatable panel (to left) and one roof-mounted one. Date unknown. (Author's image, November 2016)

The examples of the WHO-EPI installations introduce two legacies that are traced through this history: a technological one (of people and applications) and a material one (of things and equipment). The technological legacy of the earliest PV installations in Kenya being used to power NGO offices or community institutions like health centres was a connection to the realm of international development. That the NASA engineers who worked on the WHO-EPI projects were white men, set another precedent that would continue for decades afterwards. Being a white male myself I arguably benefited from this precedent too. My outsider identity, and its connotations of authority and expertise (Kothari, 2006) undoubtedly helped me gain access to the management of the Ikutha and Kibwezi health facilities. Indeed, when I walked in to the office at Kibwezi the staff there first thought I was from USAID(!)

That projects were led by outside companies, bringing outside expertise and outside technology cast Kenyans as beneficiaries or users rather than installers, technicians or engineers, and so shaped their experience of and with the technology. In Ikutha this

could have contributed to the theft of the panels. In Kibwezi, a former watchman at the health centre remembered how a white man came periodically from Nairobi to service the system, or would have to be called if there was any problem with it. Such arrangements bred unfamiliarity with the technology and left Kenyans impotent in the face of repair. The lack of ownership also left them uncertain regarding disposal. Because the solar system (and equipment) was the property of the Ministry of Health, Steve and his team could not remove the panels or refrigerator, only periodically move them from building to building. Geographer Nicky Gregson refers to such disposal-by-storage as "accommodating" (Gregson, 2011) and is a common practice identified in homes, repair clinics and on company premises too. It is returned to in later chapters. Kenyans were not only left out of the design and implementation of the technology then but often had to deal with its material legacy too – leftover panels and fridges.

Harry Burris and the household market

Another institution that was to benefit from the early forays into solar PV was the school. A project in the mid-1980s, again funded by USAID, saw solar systems installed in four secondary schools in what is today Tharaka-Nithi County to the east of Mount Kenya. Although led by a passionate young environmentalist whose race (white) and nationality (American) were helpful with regards to accessing USAID funds, it was his team of Kenyan technicians and first batch of customers – the headteachers of the four schools - that helped spread the word and made it possible for a viable company to emerge from the project. Indeed, the American's conspicuousness was actually problematic at times and would ultimately contribute to his departure from the country, leaving his employees to cement and extend the development of a household market. Their male faces beginning to cement an association of solar as a men's domain.

This section of the chapter describes the shift in application of PV from community level institutions such as health centres and schools to individual household. This shift, identifiable from around 1985, saw the environment brought in to the solar assemblage for the first time. The environment became a motivating factor for PV installations and was accompanied by ideas of appropriate technology which meant producing parts and developing skills locally. This created a role for Kenyans, or at least Kenyan men, beyond mere beneficiaries with some being trained to become technicians. In cases of breakdown this meant that the skills (and parts) were there to repair and service the systems, many of

which remain in place approximately 30 years after their installation, and some of which are still in use. The compatibility of these household systems with existing appliances and the ability to replace parts hints at an underlying ethos of bricolage and is another reason for the longevity of the systems. Having purchased systems and been trained to install, maintain and use them affected meant that users felt greater ownership over the equipment. Although, holding on to, or accommodating (Gregson, 2011) equipment remained common, disposal practices changed too with no longer functional equipment being put to use for play or educational purposes.

The young environmentalist, Harold (or Harry) Burris, known invariably to his Kenyan colleagues as Burris first went to Kenya in 1970 as a Peace Corps volunteer teaching Physics.[30] After a shortened service (he resigned one year in to his two-year post), seven or eight years working in the electronics industry back in the USA and a spell on the coast at Mombasa, Burris moved to a town called Kithimani in the eastern region where his Kenyan wife, Stella, came from. Another American, Dan Schellenberg, was living in the area at the time. He described to me their first meeting in an email:[31]

> I was driving along near the town of Matuu out of Thika heading north when I saw this white guy with tire tread sandals, a plastic woven hat and a *kikapo* (basket made of leaves) walking along the side of the road. It was my custom to pick up all foreigners no matter what, so I stopped and offered him a lift. He was hot, sweaty, smelled like he had had no bath for days, and needed a drink. We stopped at a 'hotel' in Matuu for said drink, and he asked me what I was doing in Yatta. Clearly he was new in the area because even the whores called me 'Kilonzo'--the rowdy white man--albeit I was a Baptist missionary! As soon as I mentioned the word 'missionary' he put his cup of *chai* (tea) down and said: "Yeah but do you know what you are doing?" Ok asshole, I thought, drink your tea and I'll drop you off at the next town or wherever. Me speaking Kikamba for 30 years and this loser American asking me that! "Well," he said, "not to pry but have you ever read Harold and Elizabeth Odum's book: 'Energy for Man and Nature'?" I had not, and he informed me that I therefore did NOT know what I was doing. He hauled out a yellowed, dog-eared bunch of papers and handed them to me. "Here, read this." That beat-up old book changed my life and re-directed my planning and projects for the rest of my years in Yatta, and, in fact, the rest of my life since. So yes, I knew Harry Burris.

[30] Perlin lists Burris as having started his service in 1977 (132: Perlin, 2002) yet a Freedom of Information Act (FOIA) request to the Peace Corps revealed that his service started in October 1970. Similarly, Byrne has Burris as being dismissed from the Peace Corps (82: Byrne, 2009), yet the FOIA states he resigned in November 1971.

[31] I was directed to contact Dan Schellenberg by Mark Hankins, whom I met in September 2016 at the offices of his latest solar company: African Solar Designs in the Kilimani area of Nairobi. Hankins and I also exchanged emails later in the year when I was tracking down the sites of Byrne's history.

When I visited Kithimani in November 2016 I met others who remembered Burris. Burris' former landlord, Pascal, told me that apart from trips to the market and down on his *shamba* (farm/field) by the Athi River, Burris was rarely seen by locals. While down at the river with Pascal Burris' old neighbour fondly remembered Burris collecting water there for an irrigation system he had built in his field. Dealing with solar was not a vocation for Burris but part of a broader environmentally-committed lifestyle. He spent most of his time in a solar-powered workshop he set up on the edge of town. Using off-cuts of solar panels that he would collect from Nairobi Burris experimented with several applications of solar power including a solar-powered bicycle, a solar-powered sewing machine and a solar-powered drill. This variety of possible applications demonstrates the branches of technological development that, through failure, are often forgotten. Meanwhile Burris' making use of leftovers from other applications demonstrates the limited budget that he was working with and his commitment to local, resource-conscious manufacture: both elements that fit with the idea of bricolage.

On one trip to the market Burris met another to whom he would preach the benefits of solar: Daniel Kithokoi. Burris was looking for a hand with building and installing bespoke solar systems that he was installing for schools and businesses around the country (in an interview Daniel specifically recalled installations for *Posta*, the national postal service). Many of their clients came from a connection Burris had with logistics and security firm, Securicor. Part-time to begin with Daniel would sit and watch Burris assemble various components (such as charge controllers and panel mounts) by hand in his workshop. When we met in Nairobi in December 2016 Daniel told me how Burris would tell him to "weld this, finish this and clean this, pack this and go do this".[32] Such an apprentice model is common in Kenya and is explored in more detail in Chapter 5. Soon, business spread, Daniel left the farm where he worked and became Burris' full-time assistant. Over the next two years, Burris and Daniel travelled all over Kenya installing systems.

In 1983, on one of his trips to Nairobi to collect panel off-cuts and other components, Burris met another American who was in Kenya teaching science as a Peace Corps volunteer, Mark Hankins. Hankins recalls mentioning his host school's search for a diesel generator to which Burris suggested the possibility of a solar system (82: Byrne,

[32] I was given Daniel's mobile phone number by Rob Byrne. Although Daniel downplayed his abilities in our interview, Dan Schellenberg mentioned over email that there was a Catholic priest and a German organisation (potentially GTZ, although Dan could not recall exactly) in the Yatta area at the time who were impressed with Daniel's knowledge and skills.

2009). The idea soon developed in to a project, to install solar systems in four local schools, for which Hankins and Burris successfully elicited Peace Corps approval and funding from USAID. The headteachers of the schools were not motivated, as Burris was, by the environmental agenda set forth by Howard and Elisabeth Odum (1981), but rather by the thought of saving money. This gap between motivation of users and implementers is dynamic that holds to the present day.

Perhaps in response to Odum and Odum's concluding "Call for Action":

> [you] must take responsibility to help others understand what is happening. … It is your assignment to educate; (274: Odum and Odum, 1981)

Burris and Hankins used the project as an opportunity to train a group of seven local technicians, including Daniel. In November 2016 I met Silas, another of the seven, in Chuka the town nearest to Karamugi Secondary School where Hankins had taught and where the first of the four solar systems was installed.[33] One day Silas and I took a trip down to Karamugi to find out what had become of that first system. We spoke at length to Gitari, the school clerk, who had arrived at the school in 1986, one year after he said the solar was installed. After working well for 6 years Gitari said the system was supplemented with a generator and, in 2006, a grid connection. At which point the remaining panels were "disposed" he said with 3 being sold to "private individuals" and 3 being kept, along with the batteries for practical demonstrations in Physics classes. These had all already been replaced during the 20-year lifetime of the system. Gitari showed us the one remaining original component: the panel mount, lying behind a new building on the far side of the school compound. On a different day Silas and I visited another of the four schools (Ndagani) where we were met by John, the Deputy Principal. Like Gitari, John reported holding on to the system components after the school was connected to the grid to use as teaching aids. John also showed us the panel mounts which had been reworked into basketball posts for the school playground (fig. 1.4).

[33] When I was struggling to track down any trace of Burris in the Yatta area I phoned Daniel. He told me to head up to Chuka on the eastern side of Mount Kenya and when there to ask around the town for Silas Kinyua. Even with Silas' help trying to track down the remaining three schools was not straight forward: on the phone Daniel had told me to go to Ukuu, Baka'ini and Ndagani but Silas said we needed to go to Njuri, Iruma and Kiini. Meanwhile, the only other of the four that Hankins could recall over email was Kibugwe. Resigned to the uncertainty of memory, Silas and I visited a handful of schools that he had worked on in that period. We are confident that Ndagani is one of the four original schools.

Figure 1.4. The basketball post at Ndagani School, the stands of which were repurposed from an old solar system (Author's image, November 2016).

Education and play are two responses to system breakdown explored in greater detail in Chapter 5.

Once the systems were in place at Karamugi and the other three schools and the technicians trained, demand for the technology rapidly increased: the headteachers purchased systems for their own homes and the technicians were able to buy systems too, paying for them through deductions from their wages. Silas showed me the system he had installed at his house. And a system he had installed for his brother in the neighbouring plot. Both were still in place and operating.

Around 1984/5, Burris, Stella, and Daniel moved to Embu, a larger town 44km south of Chuka south-east of Mount Kenya, to better service the growing demand in the area around the four schools (now Meru, Tharaka-Niithi and Embu counties). It was once here in Embu, that Burris formally registered a company under the name: Solar Shamba (Solar Farm).[34] The name Solar Shamba and Burris himself were relatively unknown in Embu.

[34] Jacobson writes that Burris' activities from Kithimani had a trading name: Kidogo Systems (125: Jacobson, 2004) but none of Daniel (his apprentice), Schellenberg (his friend) nor Pascal (his landlord) recognised this when I suggested it to them. Whether or not Kidogo Systems existed, or in

Instead, word spread through the technicians Burris hired – all graduates of the schools project. Although still working from his own solar-powered workshop next to the rooms he rented with his wife Stella, the registering of a company did formalise the sales and installation process: Hankins remembers Burris typing out system sizing sheets, installation quotes and letters to clients on a typewriter. Whilst their work would continue to include schools and other institutions, the main innovation of Solar Shamba was to install systems for households.

Some of the first systems installed by the company that grew out of the schools project are still functional; their system design and personal connection to the technician allowing for continual repairing when batteries need replacing. Towards the end of my time in Chuka Silas and I visited a lady at her home among tea fields on the edge of Mount Kenya National Park. Silas had found it difficult to distinguish between systems he had installed with Solar Shamba and those he had done later under his own company, Kiiru Electrical Systems set up in 1987 (10: Jacobson, 2005). This was not helped by the fact that Burris had kept all of the documentation relating to Solar Shamba installations Silas told me. We could be certain that Mrs Gakuru was a Solar Shamba customer however because as soon as we arrived she thrust a manilla envelope in to my hands. Inside the envelope was a system sizing sheet, an invoice and an information sheet all type-written and carrying a Solar Shamba header at the top of the page. When she invited us in to her house Mrs Gakuru pointed happily to the system control unit still mounted on the wall (fig. 1.5). Electricity reached this part of the country in April 2016, seven months before my visit, allowing the Gakurus to upgrade to a colour television. However, they still use the Solar Shamba system during blackouts.

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what form it did so, matters less, the word *kidogo* means 'small'. Burris was not interested in reaching scale but rather in keeping things local and appropriate.

Figure 1.5 The control unit of Mr and Mrs Gakuru's still-working Solar Shamba solar system on the wall in the hall of their home near Mount Kenya National Park (Author's image, November 2016)

In 1987, Burris moved to Tanzania where he continued to work in solar with Securicor until his death in 2001.[35] During his time in Dar es Salaam Burris met Rob Byrne, who would later become his chronicler. Hankins also left Kenya in 1987, returning to the USA after finishing his Peace Corps service. Daniel, however, stayed. At the petrol station where we had our interview he told me:

> I could not leave because my area is not the Mount Kenya area, my area is the Lowlands [near Kithimani] and I could not move from there [the Mount Kenya area] and the other thing, many of the people knew me as the head of the, the company, even most of them didn't know Burris, they didn't have contacts for Burris so they were contacting me. If they had problem they contacted me, if they had other new systems they contacted me, so I could put myself in trouble if I could have left to home, so I said, "By the way where am I going? I should continue with the job."

[35] Burris' departure from Kenya was quite sudden. The exact reasons why he left are unknown but are likely due to Burris' personality. Byrne says Burris was "known to make enemies of those he considered to be less technically conscientious than he was" (96: Byrne, 2009) and an obituary describes him as a colourful character not afraid to speak his mind (8: SolarNet, 2001). Similarly, Burris' contemporary and disciple, Dan Schellenberg told me that he had bailed Burris out after he was arrested in connection with the attempted *coup d'état* in 1982. Finally, Daniel Kithokoi suggested that a faulty installation at a school in Garissa, in the north-east of the country, had annoyed the Ministry of Energy and could have been a contributing factor.

Over the following months Daniel wound up Solar Shamba's operations. But not having access to the Solar Shamba bank account Daniel, like Silas would later do too, set up his own company to finish the installations of pending customers and such like. Daniel called his company American Solar Technologies - a nod to the mentorship he had received from Burris and also to make the association with 'the West' and its connotations of quality, modernity and technology.[36] Although, as Daniel alludes to in the above quote, company names (including BP, Total and Solarex) were not what people were preoccupied with. Despite the increasing scale of business, the diffusion of PV was still very personalised; business spread but it did so more through word-of-mouth and system visibility: i.e. panels on roof than any company logo.[37] The brand then was less the name on the components themselves (BP in the case of Silas' panel) and more the face that was installing, or maintaining, the system. The point Daniel makes here about not being able move from the Mount Kenya area links to a feature of repair work described in Chapter 5, where being local is good for business because it can mean being well-known and trusted but if one is too local then collecting payments from family and friends can be difficult. Social anthropologist, Juli Huang, writes about similar dynamics in Bangladesh more recently (Huang, 2017).

While Schellenberg was the missionary, Burris was equally zealous in his mission to spread the adoption of appropriate technology with *Energy Basis for Man and Nature* (Odum and Odum, 1981) as his bible[38]. Although with time Burris moved away from the (re-)use of scrap materials in solar systems, the compatibility of Solar Shamba's systems with existing household appliances, especially TVs, suggests an underlying ethos of the bricoleur remained, despite no longer being actually engaged in bricolage. Burris' local sourcing of materials from Nairobi and assembly of parts in Embu may have been environmentally-motivated but could also have been influenced by economic considerations. Although his nationality and race meant he could access external funding, Burris was a young man and having started out individually he did not have the reach or resources to secure equipment from further afield. Customer purchases were certainly motivated by economic reasons:

[36] Although Jacobson has Daniel's company as being called American Solar Technologies (334: Jacobson, 2004) Byrne has this company being called Solar Energy Installations (97: Byrne, 2009).
[37] Bollinger and Gillingham (2012) and Noll et al. (2014) both discuss the role of panel visibility in solar adoption in the context of the American solar market.
[38] This fervor is reminiscent of that Escobar identifies in a World Bank mission to Colombia in the 1950s where notions of salvation lead to strong convictions in one's methods (73: Escobar, 1995).

solar systems allowed Kenyans to save money (versus paying for a diesel generator or paying to charge a car battery from the grid). The broader sustainability or development agenda of the outsiders was less important to them.

Whatever the motivations by 1987 there were hints of an indigenous solar industry, one targeting households rather than institutions. Writing ten years later electrical engineers Gope, Aghdasi and Dlamini stress that

> The impact of education on the use of photovoltaics is the imparting of skills and technical know-how to the local community and the consequent reduction of the reliance on expatriate knowledge. This will produce the obvious and much needed gain in monetary wealth. Besides, such a move could see the emergence of new local companies in the industry. (223: Gope et al., 1997)

Indeed, if systems bought from Daniel, Silas or the others broke down the parts and skills were available locally to repair them. However, although the role of Kenyans was increasing it was still limited: Burris held all the documentation for Solar Shamba. Not *all* Kenyans were brought in to the technology: the headteachers and other customers remained largely outside of the systems, knowing perhaps to rotate the panels, as I was told the school watchmen used to do, but not much more. Nor were any women involved in system design or installation; solar remained a male technology.

Finally, while Hankins emphasised to me via email that the legacy of the four schools project was more the technicians trained and the beginnings of a household market than the panels or systems themselves, there is, as with the WHO-EPI installations, a material legacy to consider. And it is largely a positive one: with users having greater ownership over and understanding of the systems, many remain in place while others have been repurposed: the panel mount as a post for the basketball net at Ndagani and the panels as a teaching aid at Karamugi.

Quality concerns

The growth of a household market in Kenya however soon faced challenges. When more and more brands came in to the market and more and more people turned to make, or add to, their livelihoods from selling and installing solar equipment, problems arose in the quality of equipment itself and the quality of system-sizing and installation. The American outsider was losing a grip on the market to poor quality and mis-labelled panels from China – a new arrival to the solar assemblage. The batteries available in the market and already

in some Kenyans' homes (mainly vehicle batteries) were also not well-suited to the unique charging patterns of a solar system. Nor did all users and installers include charge controllers in their bespoke system designs which put the function and longevity of their systems at risk. As the household market expanded then the frequency of breakdowns increased. Responses to these breakdowns included designing solar specific batteries with in-built charge controllers, conducting market research into panel quality and forming organisations to raise awareness and protect the market.

This section of the chapter details the problems of quality that the burgeoning PV market faced in the 1990s. The section shows how organisational, regulatory and material responses to these challenges established a particular understanding of quality as being something inherent to the material equipment in a solar system and not, as it had been previously understood, in terms of technical training and skills. While the design of solar-specific batteries aimed to reduce breakdown and restore people's faith in solar technology it also reduced the user's knowledge of how the technology functions, keeping them outside of the technology and so limiting possibilities for repair.

In 1991, having graduated with an MSc in Renewable Energy Engineering from Reading University, Hankins returned to Kenya. Having collaborated with Daniel on his Master's research the two of them continued to work together forming a new company, Energy Alternatives Africa (EAA) in order to access institutional funds that would not have been available to them as individuals. In the following years, EAA's work remained closely aligned to development, responding to tenders and calls of NGOs and other development actors. Although EAA worked across several different countries its office was in Nairobi; Kenya was establishing itself as the regional hub for business, technology and development work (131: Perlin, 2002). Perhaps as a result of Daniel and Hankins having both been mentored by Burris, EAA also retained a focus on training. In March 1992, together with the Kenya Environmental Non-Governmental Organisations (KENGO), EAA organised a workshop in Nairobi that trained a second generation of technicians.

The first generation of technicians, trained as part of the schools' project and then employed by Solar Shamba, were mainly still involved in solar: Silas was running his company from Chuka town, while Njiru and Jua, continued installing household systems freelance in the Mount Kenya region. Ireri, moved to Thika to become a pastor. Silas did not remember the names or what had come of the other two technicians they had trained

and worked with. Regardless, in his comparison of PV market development in Ghana, Kenya and Zimbabwe, geographer Simon Bawakyillenuo, writes:

> The successes of these catalytic or pioneer social groups ... boosted other private businesses' entry into the PV rural market. (417: Bawakyillenuo, 2012)

The skills and networks of this first generation of technicians, and the continued global price drops for silicon (and so silicon-based solar panels) helped solar module brands like Alpha Nguvu, ARCO and Free Energy Europe move in, in addition to the BP panels that Solar Shamba had used.

However, this proliferation in the solar market came at a cost: systems were mis-sized, parts were missed out, panels were mislabelled, poor quality panels came in to the market and existing lead acid batteries were ill-suited to the less consistent charging profiles that come from a solar module than a diesel generator or grid connection (lower or slower charging on cloudy days for instance). Although there were some specialist solar companies such as Kenital and Telesales emerging in the 1990s, general electronic and electrical retailers in Nairobi's Central Business District (CBD) sold equipment to untrained technicians or directly to users. For the users the solar panel represented a new way to charge an existing battery based system previously charged from the grid or a diesel generator – it was not always the system that was new but often just the solar panel (see 148: Jacobson, 2007). So users and technicians would not match the size of new solar panels to the size of existing batteries or appliances at home. Cost-conscious rural Kenyans also often forewent the solar charge controller, a vital piece of equipment that protects the health and so the lifespan of the batteries (207: Miller, 2009).[39] A research article published in 1997 captures the mood of the time:

> But this private sector approach is also showing its limitations. In the absence of equipment standards and codes of practice, there are lower levels of system performance. (8: Lorenzo, 1997)

Just as solar was becoming more widespread and more affordable, damage was being done to its reputation.

[39] A charge controller prevents overcharging or draining (discharging) of a battery by stopping current from flowing in to a battery which is fully charged or out of one that is at low charge. The controller allows current to flow again, and so charging to resume, once the battery has fallen below a certain voltage or is charged above a certain level. Over and dis-charging reduce battery performance and can pose a safety risk (Hankins, 1995).

Unbranded panels from China were particularly problematic. Concerned by this Hankins partnered with American academics Arne Jacobson and Dan Kammen to run surveys of the modules available on the market and their performance with the help of two Kenyan technicians of the second generation: Henry Watitwa and Maina Mumbi (Duke et al., 1999; Jacobson et al., 2000). This community, concerned with the social and material problems of installation quality and panel quality, soon coalesced into a new NGO called the Solar Energy Network (later shortened to SolarNet). Set up in 1996 to protect the nascent solar market, SolarNet retained both international and development links: the network's archive contains many minutes of meetings, project proposals and emails with the German Corporation for Technical Cooperation (*Gesellschaft für Technische Zusammenarbeit*, GTZ), the United Nations Development Programme (UNDP) and the UK Department for International Development (DFID). Hankins served as Chairman of the organisation at various points. Although the remnants of documents produced and held by the network are kept by white Kenyan Mike Harries (a former Treasurer of the network) on his farm south-west of Thika, in its later years African Kenyans also held positions of responsibility within the organisation.

SolarNet also signalled a shift from development involvement in solar projects themselves (installations and training) towards a more supportive role (awareness and capacity-building). In addition to educational calendars and market days (open-air exhibitions for solar companies) SolarNet worked with the Kenya Bureau of Standards (KEBS) on efforts to keep the fraudulent modules identified in Hankins et al.'s surveys out of the market. The NGO also ran a database of registered technicians around the country and later assisted Henry Watitwa with the launch of the Kenya Solar Technicians Association (KESTA) that wanted to formalise this further by certifying technicians in order to address the issue of incorrect installation.

In addition to the attempts to begin regulation of technicians and of solar panels, steps were made towards improving battery performance, ever the Achilles heel of a solar system (see Chapter 3). Prime examples of this are the *Jua Tosha* (enough sun) and the BatPack initiatives, both run by EAA and launched in 1997 (Byrne, 2009). The Jua Tosha (fig. 1.6), funded by the World Bank's Energy Sector Management Assistance Program

(ESMAP[40]), was a specially designed battery for the deep-discharging that is specific to solar power. 'Deep cycle' batteries are preferred for solar systems as they allow for charging at low currents, which means they can charge throughout the day and not just at noon (when sunlight is strongest), or in direct sunlight. With stronger and heavier lead plates that are better able to resist the corrosion that comes from successive charge and discharge cycles, deep-cycle batteries are also better able to withstand the stress of repeated deep discharges, that may occur in rainy season or on cloudy days than regular vehicle batteries. BatPack, supported by The Ashden Trust, was a battery and charge regulator in one.[41] It was the first step in what would become a gradual tightening up, and closing in, of the product upon itself. The market, or user failure, to buy the right battery and a charge controller was to be corrected by bringing both elements into a single object itself.

Figure 1.6 A photo of Jua Tosha battery on display at a SolarNet event. Date and location unknown. (Author's image, November 2016)

[40] ESMAP, established in 1983 is still operating today. The partnership seeks to help low and middle-income countries reduce poverty and boost growth through investments in sustainable energy (World Bank, 2018b).

[41] The Ashden Trust is a grant-making charity. Established in 1989 the Trust primarily gives grants to projects and organisations that focus on climate change, sustainable development and improving the quality of life in poorer countries (The Ashden Trust, 2018). Related organisation Ashden plays a prominent role in the off-grid solar industry to this day running an annual awards programme for "sustainable energy pioneers in the UK and developing world" (Ashden, 2018).

As the household market expanded in the 1990s concerns about the quality of solar equipment and installations grew. Part of this concern came from the arrival of a new outsider into the solar assemblage – China, in the form of panels manufactured there, many of which were of a poor quality. This and other issues with batteries and charge controllers were addressed in various ways but always in Kenya which, by the end of the 1990s, having been the chosen site for research and implementation projects alike, was firmly established as the solar centre of Eastern Africa, if not the continent as a whole. Projects to promote design innovations demonstrate that quality concerns were no longer being addressed through the training of technicians though as Burris might have had it. Instead the problem was to be solved by bundling parts of the solar system together in to one object which, although reducing some forms of breakdown, made repair difficult and did little for the average user's understanding of the technology. The organisational response of SolarNet to gather together concerned parties and lobby for regulation, meanwhile, did increase the role for Kenyans: several held committee positions at the network. However, its ties to the international development community through organisations like GTZ meant that the outside influence remained. Similarly, in the emerging field of research around the market, Kenyans remained in supportive or assistant roles under lead researchers who were generally white American men.

Hankins and Daniel are still involved with solar today: Hankins running a company from Nairobi called African Solar Designs (ASD) and Daniel working as a driver for PowerPoint, a renewable energy company also based in Nairobi but it was the next generation of outsiders, also men, also in their 20s, who would tighten the assemblage yet further and bring together the quality-certified panel and the solar-specific battery into one product – the solar lantern.

The emergence of the solar lantern

The second generation of outsiders were, like Hankins and Burris, believers in appropriate technology and the environment. They were also committed to local skills training and developing local manufacture. Also like their predecessors they had been inspired to act after volunteer teaching placements in the region and in the early stages especially they would invest their own money in their photovoltaic experiments. They shared a commitment to using local materials and re-using materials too, although as with Burris this may have been to keep costs down as much as minimise resource use for environmental

reasons. And like their predecessors they had little engagement with the Kenyan state but instead were connected to the international development community of NGOs, charitable foundations and similar. Their most obvious difference from Burris and Hankins was that they were British, not American and so brought funding from DFID rather than USAID. The two heirs also brought media attention in to the ever-growing assemblage attracting the attention of international journalists.

This section of the chapter shows how two more individual outsiders initially experimenting with bricolage provision of solar came to be involved in commercial assembly operations before ultimately conceding product manufacture to China. With questions of quality largely addressed, or at least in view, a second challenge of the 1990s was cost. After a brief and unsuccessful foray in to system financing (e.g. World Bank's Photovoltaic Market Transformation Initiative, PVMTI), the dominant response to the price challenge was to make smaller products. Writing in 1997, solar energy specialist Eduardo Lorenzo noted that

> saturation symptoms are appearing and the typical size of systems and consequently the service level is getting smaller because the market is now moving to groups with less income. (8: Lorenzo, 1997)

The resultant solar lanterns were cheaper and presented an opportunity to reach the poorest who were until then, not just outside of the product but outside of the assemblage. The portability of these new products though re-introduced problems of breakdown as they were more susceptible to falls and theft. Efforts to set up assembly and manufacturing operations in Kenya however offered the possibility of local repair through the availability of parts, jobs and know-how that was reminiscent of Burris and Hankins' work the previous decade.

Continuing in the vein of the solar-specific batteries pioneered by the ESMAP and Ashden Trust projects earlier in the decade, the late 1990s saw efforts to combine these batteries with a light source and so produce a self-contained solar lantern that would further limit the risks of mis-selling and mis-sizing. In 1997, the DFID funded a project to design and manufacture a solar lantern for Africa (White and Fearnon, 2010). The development charity: Intermediate Technology Development Group (ITDG, now Practical Action) were tasked with designing an economical solar lantern that could be assembled in Africa using locally available materials and locally feasible production methods. The result was the Glowstar (fig. 1.7):

Figure 1.7 A poster for the Glowstar lantern that still hangs in the Sollatek Kenya headquarters in Mombasa (Author's image, December 2016)

Once the Glowstar's design was set, DFID put out the tender, worth £1,000,000, for a company to make the lantern. The tender was won by Sollatek in Mombasa; again Kenya was at the centre of a development project involving solar. Watching from the ITDG library near Coventry, UK, a British undergraduate student, called Leo Blyth, followed the project closely while writing his Bachelor's dissertation. I met Blyth, who now works as an off-grid industry specialist at the World Bank Group, at the World Bank offices in Nairobi in December 2016. It was when Sollatek, a UK-owned company, won the tender, however, that things started to go wrong according to Blyth. Sollatek immediately moved manufacture of the Glowstar to China. The promised gains for Kenyan industry through local assembly were immediately lost to the dictates of mass production – it was cheaper to manufacture in China than in Kenya. The down-sizing of home systems to lanterns also

helped make the products more affordable, albeit at the expense of capacity. But Blyth is even more despairing of what happened next:

> First application of that [the Glowstar], the company fits it with an internal circuit so that it can be charged from the mains as a back-up lantern for the urban rich, the middle-class and the next innovation was so when it senses that the power that's charging it is cut off, it comes on automatically as an emergency lantern, literally for people on the grid, who were living in fancy houses with the grid, that's what happened to a million pounds of our work to try and get out to the poorest.

Blyth first went to Kenya in 1996. He had organised himself a three-month placement with a community-based organisation (CBO) in Taita Taveta, in the south-east of the country, teaching Physics to fill the summer before starting his degree in Third World Development Studies at Coventry University. Two days before leaving the UK, Blyth received a simple solar kit (a small solar panel with two wires on the back) through the post that he had ordered after reading an article about 'DIY Solar' in a publication called Positive News. He had wanted to take solar to the villagers in Taita Taveta. The kit was the creation of another British man called Graham Knight. To assemble his 'DIY Solar' kits Knight would collect panel off-cuts (as Burris had done in Nairobi) from Intersolar, a UK manufacturer, and then add some wires to the back. With the help of crocodile clips his 'DIY Solar' kits could power mobile phones and radios, without the problems of the previous decade regarding charge controllers and unsuitable batteries. Unfortunately, that first panel through the post had arrived broken. Blyth took the panel anyway and although he could not demonstrate solar to the villagers in Taita Taveta he was able to introduce them to the idea. The ability and willingness to find use and value in damaged materials exposes his bricolage sympathies.

Throughout his studies Blyth continued returning to Kenya and spent summer holidays at music festivals in the UK selling solar lights for camping– a strategy that has since been adopted by SolarAid via their social enterprise, SunnyMoney and WakaWaka, a manufacturer of solar products.[42] A key influence on Blyth during this time was Ken Darrow and Mike Saxenian's *Appropriate Technology Sourcebook* (Darrow and Saxenian, 1993). In our interview over lunch Blyth referred to it as "a stunning book…it's like a bible". For Darrow and Saxenian 'appropriate technology' is a political project as well as an

[42] Many unbranded products found in Kenya's market today were originally intended to be, and are still packaged as, camping lanterns for European and North American markets. Chapter 2 discusses non-branded products in greater detail.

environmental one, to them it should involve the creation of jobs and skills in order to redistribute income and power (6: Darrow and Saxenian, 1993). This text and earlier work with solar cookers demonstrate that Blyth, like Burris, was a committed environmentalist. Upon graduation in 2000 Blyth moved to Kenya full-time to continue his work. Blyth and Knight like Burris showed an affinity with bricolage - assembling something from existing, available parts. One of Blyth's early experiments for instance involved locally-sourcing discarded film canisters to house three button batteries with a jack in the lid running to a small solar panel.

Graham Knight, also like Burris, was a mentor to several people. In 2001 he was approached by John Keane, another British man, who was similarly committed to the dual causes of environmental sustainability and local development. Keane had just returned from a seven-month stint volunteering in a village in the Iringa region of Tanzania, an experience he told me in our interview was "a bit like a Peace Corps type thing", where he had been struck by the frequency with which people went through batteries for their radios and the number of old batteries lying around. Over Skype in December 2016, Keane told me that it was in thinking of other ways to power the farmers' radios in Uhomini (the village in Iringa) that he turned to the internet where Graham Knight's name came up in a Yahoo search for "cheap, affordable, small solar". And so on returning to the UK, Keane, like Blyth, ordered a sample kit and, like Hankins, enrolled himself on a Renewable Energy course (with the Open University). Once he had saved enough money, as Burris had done in the 1980s, Keane would return to the village in Tanzania, and, using the knowledge from his university course, train people in do-it-yourself (DIY) solar.

Keane moved himself back to Tanzania at the end of 2003. *En route* Keane followed some more of Knight's advice and stopped by Nairobi to meet Leo Blyth. Over the next few months they ran various projects together in partnership with NGOs across the region, within which Kenya remained the capital. Training communities to build (and repair) their own solar systems, Blyth and Keane, like their predecessors, were introducing solar PV to a third generation of Kenyans. Blyth had been working for a long time with an orphanage while Keane worked a lot with the Kibera Community Youth Project (KCYP), in the Nairobi slum of the same name. Recognising that entertainment objects were in demand (the first explicit recognition of such by the outside implementers) the KCYP production line focused on powering mobiles and radios rather than providing light. Another first that occurred around this time was that the concept garnered attention outside of the environmental,

technical and development communities, when Keane's work was picked up first by the BBC (Hicks, 2004) and then later by CNN.

This media attention brought new financial interest that Keane directed towards a Kenyan, Fred Migai, who he and Blyth had trained a few years earlier. Migai was able to set up a solar panel assembly line in downtown Nairobi as a result. It was about this time that Keane and Blyth went their separate ways. Keane told me:

> after a little while basically it was clear that I needed to go and try and figure out this route myself and Leo wanted to start Solapak.

Inspired by some Chinese-made solar products that he had come across in Uganda, Blyth set up Solapak in 2004. The Solapak lantern was one of the first products in Kenya to use light-emitting diodes (LEDs).[43] Blyth established an assembly line in Karen, a wealthy suburb outside of Nairobi, and hired local young people to build the lantern. Although moving towards a commercial model, Blyth was still keen to keep employment benefits in Kenya. Like Burris (and Keane) he also sourced his parts from the River Road area of Nairobi's CBD. However, much like the Glowstar coming to cater as a back-up for grid-connected households, the Solapak lantern came to target upmarket safari lodges, as the very first systems had done in the 1980s. Things were drifting from Blyth's initial focus, inspired by Darrow and Saxenian, to get affordable power to local people with technology that

> can be understood, controlled and maintained by villagers whenever possible, without a high level of specific training (7: Darrow and Saxenian, 1993)

Meanwhile, Keane was hired by SolarAid in 2007 to set up a factory manufacturing solar lanterns in Nakuru (a town to the north-west of Nairobi). The factory was managed by Fred Migai, whose company Fomax had suffered from a break-in to its warehouse. Although solar was more and more widespread it was still not common enough to evade theft, even when it was of a Kenyan company run by a Kenyan.

Blyth and Keane, like Hankins and Burris, had followed their interests in appropriate technology and the environment to train a new generation of Kenyans basic solar skills (in both assembly and repair). However, by the end of the decade their early 2000s bricolage,

[43] LEDs are small pieces of semi-conductive material that, without a filament, are more robust, use less energy and last longer than incandescent bulbs as Solar Shamba systems did or fluorescent tubes like were in the Glowstar (1: Sollatek, 2014).

involving the (re-)use of scrap resources, had given way to commercial manufacture. And by that measure in-Kenya manufacture could not compete with the low-cost and consistent quality that Chinese operations could produce. Although the move to China made things cheaper and, especially with the arrival of LEDs, improved product lifespans it also reduced chances of repair through the reduced likelihood of locally available parts or skills. China had become then, a new outsider in Kenya's solar assemblage. Once again technical skills and local understanding were at risk paving the way for Kenya to become solely a site of use and the user as simply user.

Another new addition to the assemblage from the early 2000s was the media. The work of Knight and Keane had attracted attention not just from environment-specific organs (like Positive News, where 'DIY Solar' had featured) but mainstream outlets such as the BBC and CNN. As with project funding such coverage was helped by the access and profile Keane had as a white British man. Keane was however reflexive about his positionality. In our interview he told me "what we always wanted" was for a Kenyan or a Tanzanian to step forward and set up a business as Fred Migai had done.

The last mile at the bottom of the pyramid

Even with costs coming down, solar lanterns were still missing the poorest, often serving safari lodges and as back-up lights for on-grid households instead. In response to this emerged a new World Bank programme called Lighting Africa. Its focus was on catalysing a market for off-grid lighting through a quality standards scheme, business support and raising consumer awareness. Notably the programme did not involve funding. Funding could now come from private sources (a new actor in the assemblage) in addition to the long-standing support from development partners. Lighting Africa particularly stressed the benefits of solar to potential users, investors and governments. Beyond the benefits to the environment these were broadened to include economic savings, supporting livelihoods, improving health and improving education. While some of these were there before they had never been so explicitly stated. Although the focus was on what the product enables rather than what it does in itself, the falling price in lithium-based batteries (lithium ion and lithium fero-phosphate) also saw product performance improve during the course of the programme. Ever-brighter LEDs that could last even longer also helped improve light outputs.

This section of the chapter covers the period from 2008 to 2018 during which a new type of solar business has emerged focused uniquely on distribution, their sole business is to sell (rather than manufacture) solar products. Brands are now a feature of the market, no longer as prominent outside individuals or locally-known technicians but in company names, logos and product design. These companies (still founded and run by men) and the Lighting Africa programme have grown up amidst a wider interest in international development in two key concepts: 'last mile distribution' and the 'bottom of the pyramid' (BoP[44]). The focus of the BoP concept is to make consumers of the poor, and very often involves the last mile delivery of goods (and services) from company to customer being delivered by the poor themselves, transformed into entrepreneurs. Although the arrival of this Lighting Africa group of companies (still based predominantly outside - in Europe and North America) did bring jobs for Kenyans again they were largely in sales positions. For the first time however these jobs were available to women, indeed for some companies exclusively so.[45] In a market approach such as this the solar product becomes more a "fast-moving consumer good" (FCMG) or a commodity rather than a technical object that may need maintenance or repair. In a sector with a strong emphasis on design and quality verification any breakdown is understood to come through (mis-)use by the consumer rather than from any material defect in the product.

In 2008, Blyth saw an advert in the newspaper: "Lighting the Base of the Pyramid (LBOP)". It was a new project from the World Bank's International Finance Corporation (IFC) focused on catalysing a market for off-grid lighting. Just as it had been for the ESMAP projects, PVMTI and the DFID lantern, Kenya was yet again one of the pilot countries. For this project Ghana was the only other. Intrigued, Blyth invited the programme founder, Russell Sturm (a white American man), to come and visit the Solapak operation. Taken by Sturm's commitment to scale and market creation and dissatisfied with serving luxury safari camps rather than those more in need, Blyth shut down Solapak not long after Sturm's visit and joined the World Bank as a consultant in 2009. By which time LBOP had become Lighting Africa.[46] One of Blyth's difficulties had been to compete on cost with products

[44] BoP sometimes refers to 'base of the pyramid', the meaning of the two variations is the same.
[45] Solar Sister in East Africa, Elle Solaire in West Africa and 'iAgents' in Bangladesh (Huang, 2017) are three examples of businesses using women as sales agents to distribute solar products in rural areas.
[46] Lighting Africa has since become part of a broader Lighting Global initiative that seeks to take the same approach to markets in Asia and the Pacific. The Africa programme currently operates in 11

manufactured in China. Dropping (for now) the entertainment applications of radio, TV and mobile charging that Keane in particular had pushed, a focus on lighting made the lanterns at the centre of the Lighting Africa programme more affordable for more Kenyans.

Lighting Africa concentrated on creating customer awareness and ensuring quality with a particular focus on 'last mile' distribution. The 'last mile' describes the distance from market centres to dispersed rural communities. Lighting Africa ran a design competition (World Bank, 2012), developed a certification scheme to verify the quality of products, organised conferences and put on a series of roadshows in rural market centres to spread awareness of the growing number of solar lanterns that were available. Mounting loudspeakers on the back of open-sided lorries, the programme gathered big crowds with music, dancing and free merchandise (typically baseball caps and t-shirts) and then extolled the virtues of solar power through product demonstrations. The roadshow, a common marketing tool in sub-Saharan Africa (Amoah et al., 2009; Matiza and Oni, 2014; Patel et al., 2009), is used variously in Kenya by soap brands, mobile network providers, alternative pharmacies, radio stations, even political parties. SolarNet had also run 'Solar Days', albeit in larger towns like Bungoma and Eldoret, where solar companies would be invited to present in a static format more akin to an agricultural show.

The market focus paved the way for a new kind of business that did not necessarily manufacture solar equipment or products but concentrated solely on distributing them over the last mile. In such a climate there was increasingly less place for an organisation like SolarNet with its focus on local training and capacity-building - the network shut down in around 2009. One of the most prominent and early success stories of this new era was SunnyMoney, a social enterprise wholly-owned by SolarAid, where Keane was still working. In October 2014, I spent a day observing their sales and distribution operation at two primary schools in Kakamega County in Western Kenya.

"When we usually enter a place, because of the car, everyone knows the solar is coming." Paul told me as we rolled in to Etenje, a small market centre in Kakamega County. We were in The Solar Roller (fig. 1.8; fig. 1.9), a bright yellow mini-bus, on our way to Etenje Primary School to deliver some solar products. Paul was one of seven delivering products across Kenya as part of the SunnyMoney field team. From 10 a.m. headteachers started arriving, mainly on motorbike taxis, from approximately 50 surrounding schools to collect

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countries: Burkina Faso, Democratic Republic of Congo, Ethiopia, Liberia, Mali, Niger, Nigeria, Rwanda, Senegal, Tanzania and Uganda (2: Lighting Africa, 2017). The Kenya programme was due to end in 2018.

products that they had ordered over the phone with Paul's colleagues in Nairobi. Two hours later at 12 p.m., Paul's phone was still ringing and some plastic bags of products were still remaining: more headteachers were on their way but we had to leave for St Anne's Girls. On we rolled.

Figure 1.8 The front and side of the Solar Roller with the wording: Here Comes The Sun! (Author's image, October 2014)

Figure 1.9 The rear of the Solar Roller with the wording: Solar Power To The People (Author's image, October 2014)

The 12km from Etenje to the nearest tarmac road are an example of 'the last mile'. It is the 'mile' that Burris cycled in his tyre-tread sandals and Hankins walked from Chuka to Karamugi. 'The last mile' is problematised in the off-grid solar industry as being difficult to reach and is characterised by rough roads, impassable in bad weather, or users with little awareness of modern technologies, many of whom do not have enough money to buy them. But while it might be the last mile for NGOs and companies, like SunnyMoney, for users it is not – teachers first travel back to their schools (which for some was over an hour's motorbike ride away) and then have to arrange the final delivery to the home of the parent who bought the light.

The last mile did not just change how solar was sold though, but also what it does. The school is no longer just the place where solar is to be used (a place to be lit up), as it was in the 1980s, but a place to sell, the same money-saving pitch that had attracted the first headteachers remains but added to it are promised improvements in educational performance, health benefits and gender equality. While there has been a long association between solar power and health – the EPI installations in Ikutha and Kibwezi for instance - rather than act in a supporting role the solar lantern in itself was now improving health outcomes. Lighting Africa roadshows and specialist distributors like SunnyMoney used marketing messages to claim that through the replacement of kerosene lanterns, solar lanterns were reducing eye and lung irritations from kerosene smoke. Up until the early 2000s solar had been about appliances as much as it had been about light. But now that the solar itself was an appliance (a single, integrated product), its portable nature made it a direct replacement for kerosene lanterns, candles and battery-powered torches. Being a direct replacement meant Lighting Africa could emphasise, as the programme's name suggests, the lighting element.

Although it is called *Lighting* Africa it is phone charging and television powering that have really driven the market in the last few years (79: Dalberg Advisors and Lighting Global, 2018). Recognising the value of the TV as Jacobson had done several years earlier (Jacobson, 2007), an interviewee at the Family Bank Foundation told me how that demand for the solar systems they were distributing peaked around the time of the World Cup, while SHS manufacturer BBOXX found their customers used much more power from their systems than usual to watch a football match between Kenya and Zambia on their solar-powered TVs (Herring, 2017).

The products were different now though. The move to lithium-based batteries, predominantly lithium-ion to begin with, rather than the lead-based ones used previously helped further lower the cost of products connected to the programme. And the dawn of mobile money– the ability to pay for products remotely through a mobile phone (either by SMS or USSD)[47] – also made last mile business cheaper and easier. Also known as Pay-As-You-Go (PAYG) technology customers were able to pay in daily, weekly or monthly instalments which further reduced the (at least initial) costs. This is particularly true for Kenya where the M-Pesa (*pesa* is Swahili for money) mobile money service enjoys reach unparalleled in other African countries (9: GSMA, 2017). Once again Kenya has been at the centre of a technological step-change regarding solar. Connected to the Global System of Mobile Communications (GSM), these 'GSM-enabled' products are increasingly monitored from Nairobi, or even London. If a payment is missed then power can be cut, also remotely, so the product stops working, until payments are resumed. With the help of telephony, solar companies can now cover the last mile without the need for Burris' bicycle or Paul's minibus.

The last mile approach has also changed *who* is part of the solar assemblage. Although most of the companies that have emerged under the Lighting Africa programme, are led by men (who are often still white) the programme has also introduced a gender angle that has been missing from the history until now. Women are employed by some of the distributor companies as trusted sales agents with one, Solar Sister, doing so exclusively.

New companies, new business models, new investors, new payment systems, new benefits and a newfound place for women suggest there has been no small amount of novelty and perhaps innovation in the Lighting Africa-era. However, when situated in the history of this chapter it is possible to identify both several continuing trends and the origins of some of these apparently newer elements. The health, environmental and educational benefits of solar for instance have been there since the early days, what is new is the more recent defining of solar against kerosene, something only made possible by reducing the focus, at least initially, to lighting, hence the programme name. Similarly, although the arrival of lithium-based batteries is new it is part of the longer trend of

[47.] SMS, or Short Messaging Service, allows two phones to send and receive messages from each other. USSD, or Unstructured Supplementary Service Data, allows a phone to communicate with the network operator: users are usually presented with a series of option menus that they navigate through the keypad on their handset.

improvements in solar-related technologies, matched all the way by continually falling prices that have been the result of demand for and manufacture of other consumer electronics (like mobile phones and laptops); the benefits for solar have been collateral to the broader electronics industry. And while the sales agent model is also new it is in line with the trend of Kenyans holding junior roles to outside managers. The new, brand-conscious companies are also still headed by young, white, male outsiders who were motivated to enter the market by a mixture of 'on-the-ground' experience and academic interest much like Blyth, Keane, Hankins and Burris before them. Their race and nationality with its historical advantages has allowed them easier access to sources of funding and organisations such as Lighting Africa. Admittedly there are black Africans involved in running the Lighting Africa programme itself, complicating an understanding of outsider along lines of race or nationality and perhaps inviting us to think about outsiders according to economic status in the future – drawing a line between the upper parts of the pyramid and the bottom. Where gender is addressed it is concerning the beneficiaries or recipients of solar power and less the gender of those designing and delivering the technology which, as has been shown, has been consistently male.

What is novel is perhaps a disregard for bricolage. All the work by the Lighting Africa programme and its associates through quality standards, business support, consumer awareness and access to finance represents a wholesale introduction from outside – it reflects more the approach of the ingénieur.

The engineer's approach

In Kenya solar PV has been a development technology because it has for varying reasons and in various ways consistently been promoted by outsiders. The motivations of whom have traced the prevalent trends in international development of the time: appropriate technology, poverty alleviation and market development. Solar PV is a technology *of* development because it has enjoyed technical improvements through NASA's involvement, the BatPack and Jua Tosha projects and Lighting Africa's design competition. Solar PV is a technology *for* development because its benefits have been increasingly emphasised and become increasingly expansive, from saving money to saving the planet, protecting the environment, saving lives and improving grades. The move from the 'small is beautiful' approach (Schumacher, 1974) of some of its first proponents to contemporary ambitions of

providing universal energy access through a market that can reach scale has seen local engagement give way to uniform imposition, from bricolage to an engineered blueprint.

This closing section of the chapter concludes that the ingénieur's approach has created an overly-material understanding of the solar product which the following chapters will demonstrate has consequences for its breakdown, repair and disposal. The material closing in of the solar product: first with the inclusion of the charge controller with the battery, then the pairing of the LED within the same unit has seen the surrounding immaterial concerns such as system sizing and installation removed. The broader move from solar projects to solar products has changed the user's experience of the technology and also the jobs available with users needing less understanding of how PV works and technical positions being replaced by sales ones. Users are cast in a user role and the technology and any repair or service requirement is neglected in favour of robust products.

Although many of the institutions and innovations of the post-Lighting Africa era suggest otherwise the solar product is still very much dependent on various other parts of the assemblage, even it needs no installation or repair. It is deeply connected for instance to the wider global electronics industry from which Blyth, Keane and Burris all sourced their parts in Nairobi. Falling prices in the global electronics industry facilitated the growth of the off-grid solar industry. The products may be standalone in a technical sense but they are part of broader business, social and historical networks. These connections look set to increase as the industry moves to include more appliances with solar home system packages and turn (once again) to applications of water pumping and other 'productive uses' such as milling and irrigation.

At a recent industry gathering in Hong Kong these 'new' applications were prominent in panel discussions and in the accompanying exhibition hall. During an evening reception the founder of Greenlight Planet (one of the most successful companies of the Lighting Africa generation), Patrick Walsh, told attendees his personal history of how he moved to Hong Kong (rather than Kenya) in 2008 to try and manufacture a solar lantern that he had designed back in the USA. He said,

> And, having just graduated from college, to be honest I was mostly clueless, and I probably had no business whatsoever manufacturing anything. I had never been involved in manufacturing,… And I guess I was expecting that I could just come to Hong Kong and walk up and down the street and knock on factory doors to see who could make this thing.

In his address Walsh spoke of how the industry has evolved since that time; him and his company maturing in line with an industry that is attracting ever greater attention and investment. Walsh specifically acknowledged the role of donor funding from USAID, DFID, the Shell Foundation and others as well as the policy-oriented efforts of the World Bank in helping the industry grow and gave a nod to rival brands such as d.light and M-Kopa. At the same time that Walsh stressed his belief in a "free market" he also acknowledged the off-grid solar market as being uniquely connected to international development.

What can now be called the off-grid solar industry in Kenya remains heavily directed by outside actors. Leaders in the contemporary market such as d.light and M-Kopa predominantly also have white men at the helm with comparable stories to tell of how they started out as enterprising individuals. For the majority of this history, PV in Kenya has been a male domain. Youthful mavericks have tinkered with different forms of technology (homemade charge controllers and solar-specific batteries) and more recently experimented with different forms of delivering that technology (local assembly versus import). Inspired by their experiences of living off-grid, or with people who did, these influential individuals matched their practical experience with an academic grounding studying for undergraduate and postgraduate degrees in energy or development studies. They all either wrote a text on the topic (Hankins, 1995; Keane, 2014) or were deeply inspired by one (Odum and Odum, 1981 for Burris; Darrow and Saxenian, 1993 for Blyth).

The academic connection has continued with many of the Lighting Africa generation of companies growing out of institutions such as Stanford, Cambridge and Imperial College London. This latest generation of pioneers are equally influenced by contemporary global discourses but today these are less about appropriate technology and more about connectivity, the Internet-of-Things (IoT) and smart technology.

Another more recent pre-occupation is the brand. Unlike in previous decades when the brand was the individual (typically the Kenyan installer) or the thin copper lines and dark blue rectangle of a solar panel that would attract customers to shops and thieves to houses, companies such as Walsh's Greenlight Planet today push their brand (name, colour and form) in a competitive market rather than push the technology more broadly as their predecessors had done. The identity of these brands as coming from outside is still present however with packaging stressing that products are: "Designed in USA" or "Engineered in UK". Notable exceptions to this are companies such as Solinc and M-Kopa that stress their Kenyan identity. But beneath the Kenyan colours of the M-Kopa brand

their practices and products follow the 'outsider' line in keeping users outside of the products and not connecting to local electronic retail or local electronic repair networks. That aside the very concept of a brand is an outside concept. In Kenya for many goods, especially in rural areas, the distinction between products is more binary: between Chinese and original.

The success of the off-grid solar market since 2008 has seen a second wave of Chinese products enter the country. China is again outsider but more than that it is also outside the still-Euro-American club that dominates the Lighting Africa circles. Informed by experiences with other consumer and household electronics users in Kenya rarely distinguish between the Lighting Africa associated brands (e.g. d.light, Greenlight Planet, M-Kopa) instead they work on that more binary distinction between 'Chinese' – a by-word for poor quality, and 'original' – referring to quality products. The lack of brand significance is an example of the different planes that the international actors are working on from the local: an example of a process that Escobar found in Colombia where non-European areas are "systematically organized into, and transformed according to, European constructs." (7: Escobar, 1995). The shift to China then while resolving questions of product consistency, low costs and manufacturing at scale has also brought with it issues.

More acute politics caused difficulties for Solar Shamba with Burris' arrest in connection with the attempted coup against President Moi and for Fred Migai's Fomax whose warehouse was broken in to around the time of a fraught election in Kenya. It is not just the literal breakage of the panel Knight sent to Blyth through the post that stops solar technology from working then. Disconnects and political differences in the assemblage also play a role. These are discussed collectively in Chapter 3 under the umbrella of breakdown.

The material and geographic shift from locally assembled systems to products imported from China and Hong Kong still carries some continuities in the origins of these products and the individuals who are behind them. Assemblage thinking helps us see beyond the product and into these networks, relationships and historical precedents that have made that product possible, and crucially the times when those surrounding relationships might prevent the product from functioning.

The chapter suggests that the outside shaping of off-grid solar in Kenya is an example of pursuing development through ingénieur's thinking. The ingénieur does not

look at what already exists but focuses on what should exist[48]. By adopting this forward-looking stance and creating a whole new solution or response to a challenge rather than building from existing and accessible ideas, skills and resources as bricoleur thinking would dictate, the ingénieur forgets that which is left behind. The development of the technology over the almost 40 years covered in this chapter has left physical traces around Kenya. That most of the systems were in place when I went to visit them in November 2016 is no surprise. Similar to conversations with users of today's products there is often uncertainty over responsibility for systems and their repair or disposal. The use of old equipment as educational aids or toys is also something that occurs today. These long periods of waiting accompanied with occasional repurposing allow products and systems to disintegrate with different parts ending up in different places. These practices, and their consequences, are explored in Chapter 4 but first the next chapter looks in more detail at the contemporary market; how it has been built and what that construction means for breakdown, repair and disposal.

[48] Such prioritising is symptomatic of the vision roundly critiqued by postcolonial thinkers such as Achille Mbembe of Africa (or the Global South) as a figure of absence in the Western mind (Mbembe, 2001).

Chapter Two

Quality and impact: Devices of the contemporary market

Two trade centres, two markets

In 2012 the Lighting Africa model was expanded to Asia through a programme logically called Lighting Asia. Together they became part of a Lighting Global family of programmes which has since expanded to include Lighting Pacific and Lighting Middle East and North Africa (MENA). In the move from Lighting Africa to Lighting Global a new organisation was founded: the Global Off-Grid Lighting Association (GOGLA). GOGLA was established as an independent, not-for-profit industry association to oversee the legacy of the World Bank's initial efforts towards catalysing a market. Based in the Netherlands, GOGLA aims to increase company access to finance, lobby national governments to shape policy and globally harmonise quality standards. It consults with its members (mostly manufacturers, distributors and investors) through five thematic working groups: Business Development, Impact, Policy, Sustainability, and Technology (GOGLA, 2018).

GOGLA's work has also involved taking over the organisation of a series of conferences that Lighting Africa had begun in Accra, Ghana in 2008. When opening the fourth edition of the International Off-Grid Lighting Conference (IOGLC) at the Dubai World Trade Centre, Harry Verhaar, the president of GOGLA, said, "we need to bring those people into the global equation". Verhaar was referring to the 1.2 billion people then living without regular or reliable access to electricity (23: OECD and IEA, 2015).[49] His global equation was the off-grid lighting market. Fostered since the late-2000s by the IFC, the co-organiser of the Dubai event, under its Lighting Global programme, it is a market that, as Chapter 1 demonstrated, is rooted in international development: Verhaar's opening address was followed by a video message from Nobel-prize winning development practitioner, Muhammad Yunus, who was succeeded by the then UK Minister for

[49] The figure has since fallen to 1.1 billion in the International Energy Agency's most recent World Energy Outlook report (11: OECD and IEA, 2017).

International Development, Grant Shapps MP. Yunus talked of how dealing with individual households is quicker to implement than at a community level, while Shapps spoke of a race between companies from village to village. The script they were each reading from was of a market-based approach to development, of universal energy access provided by commercial competition. In addition to profits the off-grid solar industry claims contributions to job creation, income generation, environmental benefit, health improvement, and educational attainment. These claims were proudly displayed in PowerPoint presentations on the stage at the GOGLA-IFC conference and on marketing materials and boards in the booths of the accompanying exhibition.[50]

If you take the metro five stops east from the World Trade Centre, you cross Dubai Creek and arrive at Baniyas Square in the heart of the Deira district of the emirate. Here multi-lane boulevards become bustling alleyways, and hotels sat back from the road are replaced by cafes that spill out on to the road. Historically the commercial centre of Dubai, one area of Deira is known as Satellite Market, so named for its original speciality – the satellite dish for domestic television. Satellite Market has since diversified to become the electrical and electronic trading centre of Dubai. The area is now full of shops and indoor markets selling car radios, office fans, LCD screens and more; from component level to complete products. Satellite Market also sells solar lanterns and home systems.

During a tour of Nairobi's equivalent neighbourhood around River Road and Luthuli Avenue in the Central Business District (CBD) a few weeks earlier, I had been struck by retailers telling me that they sourced products from Dubai, especially knowing I would travel there for the conference. And so after the conference closed I moved from a four-star hotel in Al Jaffiliya (near the World Trade Centre) to a less-lauded establishment in Deira to learn more about a market that was absent from the conference hall.

Over the next five days I visited a dozen retailers selling solar products. I began by phoning one of the phone numbers I had been given by a dealer in Nairobi, I called another on the side of a product I had purchased from Kenya, and then used the phone directory in my hotel room to navigate the other shops in the neighbourhood dealing with solar products as well as walking around the district too. The retailers I spoke to were not aware

[50] I was in Dubai to speak at the conference. I presented in a session on Environmental and Social Sustainability Across the Value Chain (GOGLA and IFC, 2015), which I had helped organise through the Sustainability Working Group at GOGLA. Through my relationship to SolarAid, a GOGLA member, I was involved with the group from late 2014 until early 2018. Unlike some of the other working groups the Sustainability Working Group has had a high rotation of members and leadership. To date its meetings have been very infrequent.

that there had been a relevant conference taking place along the road. They were more concerned with telling me about the function (hours of light and brightness settings) of these products than their impact (reduced eye and lung problems by replacing kerosene). In Deira products just light homes and charge phones. This function focus perhaps stems from the close connections the retailers there have with the wider (and older) electronics market. The shops I visited in Satellite Market stocked solar products on shelves alongside digital decoders and car radios. This broader, more established, electronics market has never experienced the same efforts to catalyse or create a demand that was discussed at the conference and exhibition. The benefits of TVs and radios already being evident for those that can afford the appliances, or have the means to power them (i.e. a grid connection or a generator). Despite dealing with the same technology and dependent on the same ultimate user, "those people" that Verhaar mentioned, Satellite Market felt much further than ten minutes from the World Trade Centre.

The difference between the solar products of the Satellite Market and those of the World Trade Centre was more than *what* they do but also how *well* they do it. A uniting feature of most of the products on display at the conference was their shared certification by the Lighting Global (originally Lighting Africa) programme. One of the first activities of the programme was to set up a quality certification scheme. Companies which are willing to pay can put a sample of their products through a testing process in order to meet the Lighting Global quality standard. In order to retain their certification manufacturers must be open to their products being re-tested at intervals and accept that their products may be selected for testing from the market at random too.

While it is only the products themselves that are tested and carry the certification mark the centrality of the test and mark to the market at large, in negotiations with investors and funders, discussions with national governments, national industry bodies and national trade associations, as well as in sales training and marketing pitches makes it possible to speak of certified actors and a certified market. Certified actors are those companies, organisations, investors and individuals who use the certification (test and mark) to advance their own interests: be they political, commercial or altruistic. The phrase 'certified market' is used then to include actors who may not have direct involvement in the certification process (as manufacturers for instance), but in their exclusive interaction with manufacturers who do, they are, by extension, also certified actors; part of the certified

market. It is a term the certified actors use to describe themselves and to differentiate from those outside of the conference walls.

The approach found in Satellite Market is referred to as the *non*-certified market. The *non*- is not intended as a value judgement that gives those I spoke to in Deira, their networks and transactions, less legitimacy. Rather, because their collective identity is not defined by solar but by electronics or, very often, by nationality of origin,[51] they do not have a label for their work with off-grid solar products – itself a satellite to the main electronics industry.

During the writing of this chapter other terms were used to describe the two different approaches encountered in Dubai. These were: development and commercial, artificial and organic, created and emergent, and original and Chinese. The first three options were analytical attempts to capture the conscious identity and concerted effort of the certified market to sell its goods versus the less specialised, more free-riding approach of the non-certified market. The fourth option: original and Chinese, where Chinese refers to 'white label',[52] non-branded or counterfeit products, could have been an emic alternative coming from conversations with users, retailers and repairmen in Kenya but so far this distinction is more often used to describe mobile phones and other consumer electronics than solar products. Ultimately, the more descriptive terms: certified and non-certified, were chosen. Although loaded in their one-sided origin, they directly reference one of the defining, and first-established, differences between the two markets: quality certification.

This chapter, and the thesis, are weighted towards the certified market. With no collective identity in an industry association, no controlled supply chains, and rarely publicly available contact details (or physical premises) it is harder to access non-certified actors. This is particularly true as a white European – the non-certified market is dominated by African and Indian traders. It was clear from my short stay in Deira that it would have been difficult to gain further access in to those spaces especially where they are not as accustomed to academic researchers and research. The certified market, on the other hand, as emphasised in the previous chapter, is populated by white Europeans like myself as well as Americans. And, the certified market's other interest (alongside quality) is

[51] I found that in Deira groups of different Africans (i.e. Kenyans or Somalis) will cluster together, using the same logistics firms, working out of the same hotels or dealing with the same wholesalers.
[52] White label products are those that are manufactured by one company but bear the brand of a different company in-market appearing as if the second company had manufactured it.

impact. To measure impact, one requires researchers and so my presence as an academic in their offices, shops, and email inboxes was less unusual than it was on the roadsides, and in the cafés and budget hotels of Deira.

The distinction between these two markets is important in the later chapters of the thesis because whether a product is certified or not carries different consequences for its breakdown, repair and disposal. The certified market through its quality standards understands quality as a material measure. It seeks to delay (for we can never eliminate) breakdown through material means – by making better-performing products. In the non-certified market however less conscientious practice and lesser concern for quality means breakdowns often occur sooner. Although the certified market, through its more specialised approach and intensive presence in Kenya, has the greater potential to facilitate repair it is the non-certified market that is better placed to integrate with existing local repair networks, in part due to its close connection to the general consumer electronics market – where those repair practices are already well-established. In terms of what comes after repair the certified market is also better placed to establish responsible waste management for its products yet it is its non-certified counterparts which, through less tightly-controlled supply chains, could more readily move in to existing waste economies.

The chapter begins by moving away from Dubai to discuss the concept of market devices and their role in the creation of the two markets. The second section looks in more detail at the Lighting Global quality standards, how quality is understood and what the standards include and exclude. The third section of the chapter introduces the GOGLA impact metrics, another device that is used to build and maintain the certified market. The chapter then moves to Kenya to look at how the certified market uses these two devices to create legitimacy by lobbying local and regional governing bodies to also adopt them, thus bringing new actors in to the assemblage. The penultimate section of the chapter sets out the various sales channels through which products (certified and non-certified) make their way to sites of use in rural Kenya, based on the case of Bomet, a small town in the south Rift Valley. Here at points of sale and in sites of use the divisions between certified and non- are increasingly blurred. The chapter closes with a suggestion of what this self-designed, self-defined, certified market means for the breakdown of solar products; for their repair, and ultimately their disposal.

Market-making devices

The Lighting Global quality standards and the GOGLA impact metrics which differentiate the certified from the non-certified market are market devices. A market device is a concept first coined by economic sociologists Fabian Muniesa, Yuval Millo and Michel Callon (2007), to refer to

> the material and discursive assemblages that intervene in the construction of markets. (2: Muniesa et al., 2007)

Market devices qualify market objects, in this case the solar products, and so make economic transactions possible. They are both material and performative. That is to say that they do something and they also represent something. The quality standards for instance measure the quality of products in a material sense yet they also act as a boundary between the certified and non-certified markets. Market devices can work at an instrumental or operational level or they can work at an analytical or observational level. The impact metrics for example are an analysis of the market's effects but they are also operationalised to allocate funding or secure investment. This section of the chapter describes how the standards and metrics, as market devices, do material and performative work to construct the certified (and non-certified) market.

For market devices to intervene and perform in the market, Muniesa et al. write, they require "highly consequential investments in economic knowledge and analytical techniques" (10: Muniesa et al., 2007). And so in studying market devices "close attention" must be paid "to the different types of knowledge required to produce and stabilize [the devices]" (5: Muniesa et al., 2007). The knowledge and techniques behind and in the quality standards and impact metrics are discussed below. First, a discussion is needed of the role of market devices in market construction.

Researching the World Bank's microenterprise schemes in Cairo in the 1990s, Julia Elyachar finds that the Bank's portrayal of the market "as given" (15: Elyachar, 2005) belies the "immense labor" (17: Elyachar, 2005) that had gone in to producing it. Elyachar writes

> If there was an invisible hand, then it was quite a bricoleur, combining elements of diverse origins in [a] new and unexpected fashion. (24: Elyachar, 2005)

In Kenya in the 2010s the World Bank and the Lighting Global community of actors it has helped spawn do not claim the off-grid solar market as given. Instead their efforts to catalyse the market are acknowledged. Lighting Global credits its quality standards as a key

driver behind the growth of the global off-grid solar market. The impact metrics overseen by its successor organization, GOGLA, fit within that, predicated as they are on only measuring the effects of certified products and companies. The standards and metrics offer the stability that another economic sociologist, Neil Fligstein argues, is essential to manage the "complex interactions" (27: Fligstein, 2001) of a market. Stability, Fligstein writes

> require[s] actors who share cognitive assumptions and expectations. To get such stability, people need either long term experiences with one another such that they settle into habitual patterns, or more formal rules to govern novel interactions. (27: Fligstein, 2001)

Although born out of the longer history outlined in the previous chapter, the off-grid solar industry, in its current guise (of last mile distribution to the base of the pyramid) is still relatively young. In the absence of long term experiences between actors then the impact metrics and quality standards act as the formal rules to govern interactions between start-up companies, impact investors, NGOs and governments.

In addition to recognizing the labour that goes in to making a market, Elyachar calls on researchers to think about the

> multiplicity of markets that are the outcomes of specific forms of labor, culture, technological mixes, and modes of organization specific to time and place (Callon, 1998). (24: Elyachar, 2005)

Thinking and talking of *a* market in a singular sense however Verhaar and his fellow organisers of the conference in Dubai do not acknowledge such multiplicity nor that their quality standards and impact metrics might be grounded in a specific social, cultural and political context. Rather than talk of rules then, as Fligstein does, which could imply neutrality and rigidity this chapter, and the thesis, uses market devices. Market devices allows for an understanding of the standards and metrics as more strategic and more dynamic phenomena, grounded in a particular history and responsive to particular politics.

Part of the devices' politics can be identified in their origin. In their study of the development of the electricity industry in the USA sociologists Mark Granovetter and Patrick McGuire find that the industry formed from

> a tight web of friendship, shared experience, club activity, and domination through an industry governance structure (167: Granovetter and McGuire, 1998)

The roles for Leo Blyth at Lighting Africa and John Keane at SolarAid/SunnyMoney suggest similarly small networks were involved in the formation of the off-grid solar industry. In a later study along with Valery Yakubovich, Granovetter and McGuire, looking specifically at the establishment of electricity pricing systems in the USA explain how cohesive groups of individuals founded industry associations to protect their own interests (Yakubovich et al., 2005). It is in these industry associations, in this case GOGLA,

> that processes and relationships once shaped by individuals became institutionalized in more formal organisations, institutional alliances, standardized practices, and industry norms. (168: Granovetter and McGuire, 1998)

And it is in the process of institutionalisation that the historical developments of the previous chapter become enshrined in devices like the standards and metrics: that the quality of off-grid solar products is inherent to their materials and that their impacts are many and positive.

These socially situated origins have shaped the geopolitics of the certified market too. The outsider origins of the certified market mean most of its institutions are based in Europe and North America and managerial positions are held by individuals from those same geographies. Market devices then, like the markets they make possible, are not neutral.

Although IFC and GOGLA are not the only development actors active in the solar assemblage their early and central involvement in the market formation have made them the dominant ones. Fligstein suggests that dominant firms establish and enforce rules (devices) that "disproportionately benefit them" (49: Fligstein, 2001) and not only do such rules (devices) set the organising principles of market action but they set "the dominant cultural meanings for the market and the other firms fall in line" (31: Fligstein, 2001). Prominent peers such as the German Corporation for International Cooperation (Gesellschaft für Internationale Zusammenarbeit, GIZ) and the Foundation of Dutch Volunteers (Stichting Nederlandse Vrijwilligers, SNV), for instance, broadly work within the IFC and GOGLA established framework especially on consumer awareness and sales training. In Kenya the two development organisations jointly run the Energising Development, or EnDev, programme. During a conversation with John who works on EnDev from SNV's side he assured me that "we have to be neutral when it comes to products" although that neutrality was only with regards to certified products. And when I attended a GIZ training session (as a participant observer) in Eldoret in the Rift Valley we

were given presentations by Sollatek and Greenlight Planet (both certified actors). No non-certified actors had been invited to attend.

In addition to other development actors, a large target audience for the impact metrics and quality standards are investors and government departments. The basis of the market devices on sales data collected by GOGLA and Lighting Global and their associated policy efforts at a national level, have helped create and establish a space that less familiar international investors are increasingly willing to enter into. Although increasingly recognisant of the non-certified segment, the lack of data on non-certified sales makes it less measurable and so sales statistics, based on certified companies are used to further differentiate the two markets. The devices also reassure those in the worlds of social enterprise (e.g. Ashden), and corporate social responsibility (e.g. Shell Foundation) that the products they buy or support are of a certain quality. Then there are grants, awards and competitions run by organisations such as the Ashden Trust, the Africa Enterprise Challenge Fund (AECF) and the Zayed Energy Prize that have also been the preserve of certified companies and organisations. Those featured in the media coverage are also exclusively certified actors.

The market devices define quality on a material basis and impact on an immaterial one. The quality standards require quality parts to be used but give less regard for their assembly alongside each other or for their interaction with human, animal and environmental actants in the assemblage. The quality standards do not consider product performance in moments or processes of repair. Meanwhile the impact metrics track and account for the positive, non-material benefits of certified products but do not highlight the material risks they present when disposed of. The impact metrics do not adequately account for the material longevity of products and their potential negative environmental impact if not appropriately disposed. The two devices bring in to the solar assemblage specific understandings of quality and impact that, when enshrined in a label or on a website and tied to pre-existing authorities such as the International Electrotechnical Commission (IEC) and the Impact Investing and Investment Standards (IRIS), leave them less open to questioning and critique, turning attention instead to their enforcement and implementation[53]. The devices propagate a limited understanding of breakdown, limit the

[53] The market devices are in some ways a micro-example of the global process Chakrabarty articulates whereby Enlightenment rationalism "has been made to look obvious far beyond the

opportunities for repair and absolve certified actors of responsibility for waste management.

These two market devices and the bifurcated market they create are important for the chapters that follow because they shape how breakdown is understood (Chapter 3) and how it is responded to (chapters 4-6). The next two sections of this chapter explain how the quality standards and impact metrics make the off-grid solar products in a certain way. The two sections show how the two devices were created, how and where they are manifested (in documents and in practice) and their consequences for breakdown, repair and disposal. The chapter turns first to the quality standards.

Device #1: Quality standards

First introduced in 2009 the Lighting Africa (now known as Lighting Global) quality standards are the defining feature of the IFC programme. Reflecting on the early days of the programme in an interview, Nana Nuamoah Asamoah-Manu, Country Officer for Lighting Kenya, told me that the standards were: "the first major thing that we did". The standards are a series of indicators that if matched or surpassed allow a product carry the Lighting Global certification. They exist "to protect buyers and consumers and effectively regulate the marketplace" (Lighting Global, 2018b). They also serve to give investors' confidence in the market. Since 2016 the standards have been overseen and developed by the Technology Working Group at GOGLA, previously the Quality and Standards Working Group. The transition of responsibility for the standards from the IFC to GOGLA is part of a broader shift between the two organisations in recent years as GOGLA looks to take on more of the Lighting Global programme legacy. Part of the development of the standards saw a second set introduced in December 2015 to cover SHSs. To gain certification, at the time of writing (Version 7.1 for Pico-PV, Version 2.3 for SHS kits), pico-products or SHSs must meet a minimum benchmark in six areas:

- Truth in Advertising
- Lumen Maintenance
- Health and Safety
- Battery
- Durability and Quality

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ground where it originated." (43: Chakrabarty, 2008). The devices take on an authority that obfuscates their political and cultural origins.

- Warranty (2: Lighting Global, 2017a)

Product test results are valid for two years, during which time products can be tested in-market and at the end of which products must be *re*-tested for renewal of the certification (1: Lighting Global, 2018c).[54] This section of the chapter splits the six test measures into two groups:

1. Internal, product performance (covering Lumen Maintenance, Health and Safety, Battery, and Quality and Durability)
2. External, product surroundings (Truth in Advertising and Warranty)

It is argued that while the standards put the responsibility on manufacturers to make products that perform consistently, to offer a warranty, and to tell the truth to consumers, those responsibilities are limited in time and in scope. Firstly, the internal elements of the product's performance are tested only in the time that it is functional, its performance in other stages of its life such as repair, recycling, or disposal are not included. Secondly, the external elements of advertising and warranty do not assess whether or not that warranty is serviced, nor how, once the product is in sites of use.

Although a critique could be made of the way the standards were developed, are calculated, or tested, this section of the chapter is instead focused on what they do not include. The focus on the material quality of the product neglects non-material factors that can affect performance. The standards' focus on the inherent properties of the materials (lumen brightness, number of battery cycles, physical resistance of plastic) ignores the assembly of the materials and the wider assemblage of the product's interaction with humans and animals, where problems arise and breakdowns occur[55]. The quality standards protect individual elements of the product and the product itself from particular breakdowns but as Chapter 3 will demonstrate there are other types of breakdown that have little to do with the material integrity or functionality of the product. Nor do the standards address how the constituent materials connect to each other in a way that may facilitate repair. The quality standards give little to no consideration to how the parts and materials be deliberately (dis)connected. Their understanding of durability-through-strength, rather than durability-through-repairability means the standards promote designs

[54] The selection of products and the frequency of 'Market Check Testing' is at the discretion of Lighting Global (1: Lighting Global, 2018a).

[55] This limiting of the standards to technical elements is a micro-version of what Ferguson (1994) identifies in development at large. In Lesotho, Ferguson finds that standardisation created the homogeneity necessary for the development apparatus to intervene and then to measure that intervention.

that cannot or do not disconnect. This has consequences for the quality of waste materials the product becomes later if materials are mixed or contaminated their re-sale or re-cycling becomes more time and so cost-intensive or simply impossible. There are of course reasons for the exclusion of these elements. It is not then the exclusion that is critiqued per se but what it reveals in the way the certified market is imagined and understood by its proponents. The standards are a central market device that reveal the priorities of the certified actors. Their overly material nature has consequences for the environment, the user and the repairperson.

Internal product performance

Of the six measures within the standards *Lumen Maintenance* is perhaps the one most visible to the user. The light output of products after 2,000 hours of operation needs to be "≥85% of initial light output" (2: Lighting Global, 2017a). If a product dims, the user notices. In a survey of 262 users across 9 counties, 32 people complained of their products having become dim.[56] Although an important measure, there is an irony in this being the sole mention of maintenance in the standards. It is not however maintenance with hands or by human intervention but a maintained level of performance inherent and in-built to the LEDs within the product. The measure does not include for example the ability to replace the LED – another form of maintenance.

To pass the *Health and Safety* measure batteries are not allowed to contain more than trace amounts of mercury or cadmium, as defined in the European Union (EU) Battery Directive (2: Lighting Global, 2017a). The measure also says that if an AC-DC charger is included with the product that it must be approved by another consumer electronics safety certification.[57] The concern here for both human and environmental health is commendable, yet limited: there is no control for instance on the levels of cobalt or lead that batteries should contain which are both also harmful (Brock and Stopford, 2003; Demayo et al., 1982) and common to products in the industry. Nor is there any comparable stipulation on the metal content of the panel which sometimes contain lead or cadmium which are both again known to be hazardous (Godt et al., 2006). The metal make-up of

[56] This survey is discussed in greater detail in Chapter 4.

[57] The accepted marks are "UL, CE TÜV Rheinland, CCC, or similar" (5: Lighting Global, 2017a). These are explained in more detail in the Lighting Global *AC Charger Safety Approval Policy* (Lighting Global, 2016a).

accessories such as liquid crystal display (LCD) screens in TVs which often contain mercury - another dangerous metal (WHO, 2017) is also not included.

History suggests (see Chapter 1) and interviews also attested that batteries are central to the performance of the solar product but are also often their weakest part. Perhaps recognising this, there is a measure in the standards that applies to the *Battery* specifically in addition to its inclusion within the Health and Safety measure. The battery-specific measure stipulates that the battery in products "[m]ust be durable and adequately protected" (1: Lighting Global, 2017a). Like with lumen maintenance, the durability and (electrical) protection of the battery is noticed by users. If a battery is not performing properly, products will not offer light or charge for as long. In the same survey mentioned above 19 users spoke of their products not lighting for as long as they had done previously, indicating battery wear. However, again similar to the lumen measure, there is no recognition of the position and replaceability of the battery.

The fourth area that focuses on the internal performance of the product is *Durability and Quality*, which requires products to have "[a]ppropriate protection to prevent early failure" (1: Lighting Global, 2017a). Rather than referring to the electrical protection of a charge controller as in the Battery measure, here 'protection' is understood in a more physical sense. It covers Physical Ingress Protection (for dirt and dust), Water Protection (for rain and moisture), a Drop Test (from 1m), soldering quality (as defined by IEC), switch durability and Strain Relief Durability (of cables). Durability and quality matter and these areas cover the key causes of failure that users spoke of in the survey. 26 users mentioned a fall or water damage as having caused them problems with their product.[58] The measure however is based on a material understanding of durability. The measure does not allow for durability that draws on other elements of the solar assemblage, namely human hands, skill and spare parts to replace the LEDs, battery, switch or cables that could keep products running longer.

The four internally-focused measures then are temporally limited. While they recognise the material longevity of the weakest, most fallible components: the batteries and the LED, they do not acknowledge those components that last magnitudes longer: like the decades-long lifespan of a solar panel or the centuries-long lifespan of a plastic casing. The measures of product performance are also limited in scope: no recognition is given to the *assembly* of these materials and the possibility of repair; so that when failing, or falling

[58] A fuller discussion of product breakdown is made in the next chapter, Chapter 3.

below the levels required, those shorter-span components (battery and LED) might be replaced and match the longer lifespan of panels and plastics. The standards understand the product not as a series of parts connected both to each other and users and repair-people in the solar assemblage but instead as a set of discrete materials with inherent properties.

External, product surroundings

Although not compulsory companies sometimes mark the Lighting Global certification on their packaging and at times in advertising materials. What the standard does specify, under the *Truth-in-Advertising* measure, is that any information companies do provide to the user through labelling is "[a]ccurate" (1: Lighting Global, 2017a). This could include information such as brand name and model, light output and run time, or the use of auxiliary appliances. This information never seemed to be that important to users I encountered. Instead of receiving information through packaging, which could even be left at the point of sale, users were more likely to remember the information given to them from a sales agent or retailer. However, there did appear to be a discrepancy between the information specified and the product performance: in the survey for instance 18% of products were not working 18 months after purchase, despite the same users believing their products would last 42 months (on average).

The second measure that applies to the product surroundings, the external elements of the assemblage is that of *Warranty*. To pass this measure products must have a consumer-facing warranty "with at least one year of coverage" (1: Lighting Global, 2017a).[59] The measure acknowledges, despite the protections and material qualities specified above, a product's ability to break down (if not its propensity to do so). However, the standard does not concern itself with the quality of that warranty: companies only have to offer a warranty, they do not necessarily have to honour it. Nor is there any verification of their presence or ability to do so. Further, while the measure states the warranty information must be written "in a regionally appropriate language" there is more to the consumer's comprehension than whether the language is locally understood, there is a question about whether the practice is locally understood, whether it is locally practiced. The concern then for after-sales that the warranty represents is limited in time (users

[59] For SHSs this must be two years for the main system (i.e. the battery and lights) with one year for "most included appliances" (i.e. TVs and radios; 4: Lighting Global, 2018e).

believe they will last much longer than the period of warranty) and in scope (it only needs to be offered, not acted upon). Nor does the warranty require collection or take-back of products, that responsibility (most likely coming after the one-year warranty period) is not something the certified actors are required to concern themselves with.

The tying of testing methods to existing IEC practices and pegging safe limits to the EU Battery directive gives the Lighting Global standards a sense of broader legitimacy, connecting the certified market in to wider, older regimes of governance. At one end the quality standards broaden the solar assemblage by bringing these other bodies as well as testing laboratories in to it. At the other end the quality standards limit the assemblage, ending the market at the point of sale (because the warranty does not need to be honoured, only offered). The standards impose certain geopolitical boundaries to the market too; the fees involved to secure certification limit access for Kenyan-owned and Kenyan-run companies. One manager of a Kenyan solar company told me "it's a long process and an expensive one" with another telling me it "is very expensive for us".

The crucial point here though is *what* of the product's performance is tested. As a market device the standards both reflect and shape the nature of the products that make up the certified market. Performance is only measured of functionality not non-functionality (repair or recyclability). Components are tested but not how they are assembled, and so could be disassembled. The standards define quality in a material way that neglects other aspects of the assemblage where quality could be important: the quality of service, the quality of information, the quality of relationships et cetera. Quality is also limited to one lifetime of the product and not the possibility of second or third lifetimes through the continual replacement of parts. For SHSs there is an extra measure called 'Consumer Information' which at least acknowledges the concept of replacement, if still allowing manufacturers to make a

> clear consumer-facing statement that the batteries and other components are *not* replaceable (Emphasis added - 4: Lighting Global, 2018e).

The next section explores what these quality products do (as a whole) as opposed to what their component parts can do independently.

Device #2: Impact metrics

In January 2016, a couple of months after the conference in Dubai, a set of metrics to measure the social impact of the off-grid solar industry were approved by a global initiative called Impact Reporting and Investment Standards (IRIS). IRIS aims to increase the scale and effectiveness of impact investment through better measuring impact. The impact metrics for the off-grid solar industry are a second market device that both creates and protects the certified market. In 2013 GOGLA convened a Working Group, as they had done for the quality standards, to

> produce a harmonised industry standard for reporting on social impact for consistent use across the sector. (5: GOGLA, 2016)

The first version was released in June 2015. The target audience for this market device is regulators and investors, the metrics exist

> to attract investment, working capital, and regulatory support for the off-grid lighting industry that will help the sector to scale (5: GOGLA, 2016).

At the time of writing (August 2018) these refer only to pico-solar products. However, the Working Group is looking to expand these, as the Quality standards have done, to cover SHSs (42: GOGLA, 2016). The current metrics, Version 2.0, (released in January 2016 and aligned with IRIS)[60] cover six areas:

- Lives impacted
- Livelihoods supported
- *Status quo* lighting sources no longer in use
- Change in available lighting service
- Money saved
- Greenhouse gas emissions offset (4: GOGLA, 2016)

This section of the chapter groups these six metrics into three groups:

1. Energy access (Lives impacted, Change in available lighting service)
2. Economic impact (Livelihoods supported, Money saved)
3. Environmental impact (*Status quo* lighting sources no longer in use, Greenhouse gas emissions offset)

[60] An updated version of the metrics were released in September 2018 but unfortunately this was too late to be analysed here.

In reflecting on what responsibilities the metrics encourage companies, and their products, to claim and which responsibilities they do not measure or advertise, it is argued that similar limits to scope and time as found with the quality standards allow the metrics to track only positive impacts and only those that occur during the period when the product is fully functional. In tying the measure of energy access to the source (the sun rather than kerosene), rather than the material product that makes that energy usable (the solar product rather than the kerosene lantern) the impact metrics are able to overlook the greater recyclability of kerosene lanterns (glass and steel) against the potentially more damaging solar product (containing toxic metals and plastic). In limiting economic impacts to the first lifetime of a product (assumed to be 1.5 times the warranty period; 6: GOGLA, 2016) the metrics do not account for possible positive impacts available through repair or refurbishment that could give a product a second lifetime. Finally, in limiting environmental impact to emissions offset, the environmental impact of the material product at the end of its lives is not accounted for, when products may be disposed of in local environments.

A critique could be made of the metrics themselves, their calculation and their measurement. A lot of the metrics, for instance, are based on problematic assumptions (i.e. products being used at home, rather than at work or school; or all members of the household having equal access to the product). However, like with the critique of the standards the focus here is not on how the impact metrics are calculated but more on what they do not measure, the impacts they do not promote. If the quality standards are too material in their focus on inherent material properties and performance of discrete components, then the impact metrics are too *im*material in their focus on intangibles such as light, money and gases, at the expense of the very tangible, very physical, impact of waste batteries and plastics in the ground.

Energy access

The impact metrics define energy access as having *more* light for *longer,* and it being generated from *modern, renewable* sources. To measure this, the metric is split into an "improved" source and an improved output (17-19: GOGLA, 2016). For improved source the metric is based on solar products being used in households where there was a 'worse' energy source beforehand. According to the survey this was true in 75% cases. 'Worse' sources are sometimes referred to by certified actors as 'traditional' and include kerosene,

candles or non-rechargeable battery-powered torches and lanterns. The metric assumes a one-for-one replacement of that 'worse source' and that it is no longer in use. But in some of my home visits, I was told and saw that 'worse sources' came back in to use especially when the solar products had had problems. Similarly, in the survey a third of those spoken to told us they had continued to use the 'worse' source alongside their solar product. While solar does provide more light for longer and is renewable, the simplified narrative of like-for-like replacement and the traditional-modern energy source binary may appeal to investors and policy makers but it is not reflected in practice.

Economic impact

The economic impact covers two metrics: *Livelihoods supported* and *Savings on energy-related expenditure*. The livelihoods metric is then split in to two categories: those who use the products for their business (i.e. to charge phones or to light a kiosk) and those employed in the distribution chain. The limiting of the employment category is telling in itself: that jobs at the management, design, engineering or finance stages of the supply chain are not considered. For most of the certified actors these jobs are at headquarters, often outside of Kenya. Further this means the metric does not include those working outside of the certified market: either in servicing products or selling them alongside other electronics. Admittedly the Impact Working Group are reviewing the inclusion of the distribution chain part and so it may be removed from future versions of the metrics (16: GOGLA, 2016). Another limit to the livelihoods measure however is that it does not account for jobs lost through the growth and scaling of the market: this could be people involved in the kerosene supply chain for example (see 158-159: Davies, 2014)

The *Savings on energy-related expenditure* metric is calculated as the amount of money a household saves on lighting and phone charging after the purchase of a solar product, for the lifetime of that product. Possible savings on other related expenditure such as radio batteries are not included. The main issue with this metric however is its basis on a product lifetime of 150% of the warranty period. In ignoring the possibility of repair and extending product lives beyond that time period the metric does not account for possible further savings in pursuing a repair rather than re-purchase.

Environmental impact

The environmental impact includes measuring status quo lighting sources that are no longer in use and greenhouse gas emissions offset. In addition to my own empirical examples other scholars have found evidence of energy stacking where multiple different sources are used in tandem (Brew-Hammond, 2010; Hiemstra-van-der-Horst and Hovorka, 2008). This further undermines the usefulness of a metric that risks simplifying the complexities of household energy politics.

Also, in measuring the relationship between energy source (kerosene/sunlight) and output (light), both immaterial elements, the metric slides over the hardware in between; the object that converts that source in to that output. The fuel is what is being measured, not the hardware.

The second measure of environmental impact: offset greenhouse gas (GHG) emissions, is not currently in use (22: GOGLA, 2016). This is perhaps because, as the working group itself concedes, it is:

> [i]ntrinsically difficult to pin down a precise estimate for life-cycle impacts because of the dynamic and connected nature of global economies. (23: GOGLA, 2016)

While GHGs are important there is more to the current global environmental crisis than emissions, such as electronic waste, for instance. It is of little surprise that the environmental impacts are the least measured as they are in many ways assumed, and assumed to be positive.

In the introduction and background to the document that outlines the current metrics it mentions that some benefits are difficult to track:

> A key challenge to building standardised social impact metrics is that many of the *benefits* from off-grid lighting are difficult to track directly: for example, improvements in educational, health, and livelihood outcomes for the people who adopt improved lighting (5: GOGLA, 2016; emphasis added)

These areas: health, education, and the productive use of energy and income of households are the focus for the future development of the metrics (45: GOGLA, 2016). While some of the other impacts suggested in this section (e.g. livelihoods through repair or environmental impact of hardware) would also be difficult to track and would also rely on a range of assumptions to the ones already in use, they would give a more holistic perspective on the impact of these products.

The indication of the future direction of the metrics confirms that they will continue to measure positive impacts, confirming itself not as neutral assessment of the impact but rather as a normative one that aims to support the industry. The Working Group explains in one document how the metrics allow adopters to "speak with a unified language of *positive* change" (5: GOGLA, 2016; emphasis added). Future metrics will not incorporate negative impacts such as the interaction of lithium with ground water or the contact between soil and plastic. In not recognising these negative impacts and pursuing a positive message of growth the certified market will ironically increase the frequency and size of the problems at the end of a product's life by generating more waste, earlier. Nor do future versions of the metrics look likely to include positive afterlife impacts that could be had on repair and waste livelihoods, or the economic savings to customers through the refurbishing or re-selling of products that increases energy access, as well as the ultimate metric: profits.

It was important for this section to look at the key clauses from the metrics, like those of the standards before that, because it is this knowledge and these analytical techniques that constitute the market device. The metrics strengthen the role of impact investors within the solar assemblage and also legitimise a particular type of quantitative knowledge regarding users' experiences of products. By removing differences of product and context, impact metrics facilitate comparison across countries and companies. "With standardized elements," writes Ferguson "things are much easier." (259: Ferguson, 1994). The metrics, through their basis on unit sales, are able then to facilitate the growth of the market. However, such an immediate, short-term measure has little relation to actual or later impact and does not capture whether or not those units are in use or still functional years later. As evaluation consultant, Basil Cracknell, has written:

> impact cannot be measured at project completion; it cannot even be measured with any finality a few years after completion, but at least one can get a much better indication then of what the ultimate impact on the target population is likely to be. (28: Cracknell, 1996)

Basing impact measurement at the point of sale is a flawed method of calculating impact. Despite Cracknell's recognition in 1996 that

> increasingly impact assessment is coming to be regarded as one of the most important types of evaluation (26: Cracknell, 1996)

in international development, the academic interrogation of impact metrics in the sector, and such flaws, is all but non-existent.

If standards shape the boundaries of the product, then metrics shape the boundaries of the market. One edge of the market is three years after the sale of a product, as the metrics do not account for possible future or extended lives beyond that. Metrics, like standards, can also extend on to users, so that those not having a positive impact (through using solar) can be portrayed as having a negative impact (by using kerosene). Similar to the quality standards connections to benchmarks and tests of the IEC, linking the impact metrics to the official IRIS catalogue gives the GOGLA measures credibility to a wider audience. The external validation of its market devices also help the certified market in its translation of the devices in to favourable sales and policy environments in the countries where the solar products are designed to be used. The implementation of the certified market devices is discussed in the next section.

Lobbying for local policy

On the second day of the Dubai conference I attended a session called: 'Achieving National Level Policy Change: The Case of Kerosene Subsidies, VAT and Tariffs, and Quality Assurance'. I went partly because one of the panellists was a Standards Officer at the Kenya Bureau of Standards (KEBS) – an agency I wanted to speak to, knowing the centrality of the Lighting Global standards to the market, but was yet to secure a contact at. At the end of the session I approached the Standards Officer, Alex Mboa. Before I could even ask, Mboa invited me to come and visit him at his office in Nairobi where we could discuss more. And so, after my 10 days in Dubai I returned to Kenya (in November 2015) and made my way to Mboa's office in the south of the city. The KEBS Head Office is just off of Mombasa Road, conveniently, and strategically, situated between the retail hub of the CBD and the industrial warehouses that line the road out to the city's airport and ultimately the coast. During our meeting Mboa told me how Lighting Global had brought a draft set of standards to the bureau and were asking for national standards to be put in place in order to give their aspirational quality standards a legal basis.

This section of the chapter, like the session in Dubai, discusses quality standards, taxation, and government policy. I argue that the quality standards and impact metrics are used by the certified actors as market devices to advocate for favourable policies in the countries where they work. Embedding the limited market devices into national regimes of

governance, like the linking of their calculation to international bodies, gives them a credibility and legitimacy in which discussion becomes more a question of how effectively they are implemented rather than discussing, as the previous sections of this chapter did, what the devices might exclude or who and what they may favour. Advocacy efforts serve to favour certified actors only and not the non-certified actors. The focus of these policy efforts has been on: aligning national standards with the Lighting Global ones, lobbying for VAT exemptions on certified product imports, and on greater recognition of off-grid options in national energy policies; all of which aim to increase sales. Taking each of these three areas in turn the section shows how the certified market neglects responsibility for other affected policy areas such as in-country manufacture, product repair and waste management. Enlisting national actors in to the solar assemblage, also further reduces the agency of domestic players to determine their own corporate practices (Michael, 2003) and could be seen as part of a macro-level imposition by the outsider.

Making global standards national

North of Popo Road and over the railway from the KEBS headquarters is the Upper Hill district of Nairobi. The district is home to the World Bank's Kenya headquarters, and the national Energy Regulatory Commission (ERC). This geographical proximity to the World Bank was echoed in an interview with Nickson Bukachi, a Technical Officer for Renewable Energy at the ERC. Just under a year after my meeting with Mboa, Bukachi told me about a meeting he had had with the World Bank the week before our interview. In the meeting Bukachi said that the World Bank really wanted to know what the ERC was doing in relation to providers of smaller systems because: "without regulation, them [the World Bank] giving finances now becomes a challenge". This requirement of regulations as a pre-requisite for financial support is an explicit demonstration of the outside influence of the certified actors. The ERC exists to regulate, and collects data on, energy products and industries in Kenya. Most of its work within solar was to set up a standard for technicians installing the battery-based systems mentioned in Chapter 1, the component-based ones prominent in Satellite Market. The current three-tier classification of systems "did not capture the small, small systems" Nickson said; these are "systems that do not require any installation". The aim of the domestic regulations had been to address the more historical concerns of bespoke (component-based) solar home systems being over-sold or under-sized (see Chapter 1), not the pre-defined plug-and-play variety espoused by certified actors. Nickson

however was reluctant for the ERC to regulate the smaller systems as well. He saw a limit to intervention in the market. Straying from the Lighting Global narrative he told me:

> But there then you see it's also not good to regulate everything because there are things … that fall in place using competition, out of competition. So if you sell your products higher and there is someone selling it cheaper and it works then of course people will go for the other product.

The push from the World Bank away from licensing technicians to certifying products perhaps revealing the belief and conviction held by the certified actors in the ability of these products to operate as objects independent of their interaction with humans rather than as part of the solar assemblage. While the ERC's focus on the component-based systems reflects the wider prevalence of these systems (although exact figures are unknown). Again economic knowledge, in this case sales data, is integral to the market device and gives it power to act over areas where the equivalent knowledge is not available i.e. for the non-certified products and component-based systems.

Tax: Exemptions and definitions

Moving further north from Upper Hill, on the other side of Uhuru Park, is the head office of the Kenya Private Sector Alliance (KEPSA). Despite indicators from KEBS and ERC to the contrary, I was trying to find evidence of a domestic off-grid solar agenda and wondered if KEPSA might offer some. As we sat across from each other in a large board room in September 2016, Laureen Wesonga, a Policy Analyst at the alliance told me that the Kenya Renewable Energy Association (KEREA) had recently given KEPSA a proposal regarding the removal of VAT on solar equipment. Laureen explained:

> they [KEREA] want to see how they can get the tax, the VAT on renewable energy revised on, ok, what they frame as 'solar appliances' because currently the definition is so narrow that pretty much, we're missing out on opportunities to getting in equipment at a lower cost.

What Wesonga and KEREA were referring to was an amendment to a piece of regional legislation. In June 2016 the East African Community (EAC) separated electricity generation from appliances in the application of VAT.[61] Assembled solar products remained "zero-rated" a move to help enable the market (by keeping costs down) but imported additional

[61] The EAC is an intergovernmental organisation that aims to increase cultural, political, social and economic integration between its six member countries: Burundi, Kenya, Rwanda, South Sudan, Tanzania and Uganda (EAC, 2017).

parts or accessories (such as TVs within SHS kits) would be subject to taxation.[62] KEREA was asking KEPSA if they could push for the reversal of this amendment with the East African Business Council (EABC).[63]

By broadening the definition of a 'solar appliance' to include TVs and radios that are packaged with a solar system, KEREA would be able to lower the cost of imports for the its members, most of whom are, in turn, members of GOGLA, as is KEREA. While KEREA and KEPSA are both national bodies, the campaign to remove VAT duty on accessories for solar systems was initiated by GOGLA. The month before my meeting with Wesonga the association had written a letter to the leaders of the EAC on the issue:

> Let us not allow the omission of a few vital words in the provision to undermine the growth of such a vibrant and promising industry, at a critical time. 'Accessories and spare parts' should be explicitly included in the list of import tariff exempted goods. (1: GOGLA et al., 2016)

Although the letter mentions "spare parts" the only examples listed in the letter are "accessories such as fans, fridges, radios, or TVs" (1: GOGLA et al., 2016). No mention is made of replacement batteries, modules or LEDs. The certified market favours growth through the sale of more appliances over extending the lifetime or preventing the breakdown of those appliances. The point for this section is that certified actor (GOGLA) seeks to use its market devices (only certified products would be zero-rated) to gain favourable conditions in the country and region.

Policy

Less than a kilometre east of KEPSA are the offices of the Ministry of Energy and Petroleum. In September 2016 the Minister for Energy and Petroleum, Charles Keter, opened a different conference, that of the International Renewable Energy Agency (IRENA[64]) with words of Kenya's commitment to renewable energy. I was sceptical however given that just the previous month the government had announced that Kenya would be exporting its

[62] When goods that would otherwise be liable for VAT are given a tax rate of 0% they are said to be zero-rated.

[63] The EABC "provides a regional platform through which the business community can present their concerns at the EAC policy level, with the overall aim of creating a more conducive business environment through targeted policy reforms." (EABC, 2018).

[64] IRENA is an intergovernmental organisation that "encourages governments to adopt enabling policies for renewable energy investments, provides practical tools and policy advice to accelerate renewable energy deployment, and facilitates knowledge sharing and technology transfer" (IRENA, 2018).

first barrels of oil by June 2017 (Namunane, 2016).[65] Watching the minister on stage at a well-known Nairobi hotel I could hear Wesonga's voice in my head:

> …it's one thing for a government to tell you 'we are keen on renewable energy' but it's another, what is it they are doing to promote that renewable energy you know? The devil is in the detail.

I had heard similar from Willis Makokha, the head of the Renewable Energy Division at the Kenya Industrial Research and Development Institute (KIRDI), who told me that small solar was not a focus for the government. Of course, there is a hint in the name of the Ministry itself that priority is not towards renewables.

The Kenyan government's role in the off-grid solar industry is also debated in the literature: Ondraczek (2013) and Hankins (2000) argue it has been limited while Bawakyillenuo (2012) and Byrne (2009) put more emphasis on its contribution. Most scholars though recognise the role of external actors as having been more influential. As highlighted in the previous chapter in earlier decades these actors were individuals (Burris, Hankins, Keane and Blyth). In more recent times the outside influence has come in the form of institutions and companies, although still from the UK (DFID) and the USA (IFC). DFID for instance are pushing for off-grid options be recognised as electrification or to be built in to rural electrification programmes. DFID's Energy Africa campaign which was actually launched in Dubai by the then Secretary of State for International Development at the UK government, Grant Shapps MP sees DFID lobby national governments across Africa to sign compacts that commit to activities such as adopting Lighting Global standards, removing import duty on solar products and incorporating off-grid options in to government policy (DFID, 2015).

The close relationships between domestic and international institutions: Mboa having been invited to the GOGLA-IFC conference in Dubai and Bukachi having met with the World Bank, highlight the influence that the international certified actors have over domestic agenda-setting and so decision-making. And the focus on import policies and, to a lesser extent, energy policies, reveals that that agenda is geared towards market growth with little concern for the market's material footprint and later concerns such as product repair or waste management.

[65] Although the plan would later stall (Okoth, 2017), in June 2018 Kenya exported its first barrels of crude oil (Kiplang'at, 2018).

Selling the standards and the impact

Despite the efforts to keep them out of Kenya through the aligning of local policies to supra-national standards non-certified products are still present in the country. In January 2016 I moved to Bomet, a town in the south of the Rift Valley, 220km west of Nairobi. Over the course of the three months I stayed there I saw both the suave M-Kopa shop (a certified manufacturer and distributor) with its Apple Shop aesthetic (fig. 2.1) and the independent electronic store selling certified and non-certified products side by side (fig. 2.2).

Figure 2.1 The inside of the M-Kopa shop in Bomet which opened in early 2016 near the town's old stadium (Author's image, March 2016)

Figure 2.2 *Olesoi Electronics*, an independent electronics store on the main road through Bomet, opposite the bus station (Author's image, March 2016)

I also encountered mobile sales agents selling certified products and independent hawkers marketing non-certified ones. There were roadside tables selling certified products and second-hand products and many of the banks, microfinance institutions (MFIs) and savings and credit co-operatives (SACCOs) in the town were also engaged, or had previously been, in partnerships with certified actors to distribute products to their members and customers.

Previously no more than a transit trading centre between the capital, Nairobi, and Lake Victoria to the west, Bomet has grown noticeably since 2010 when a new constitution introduced a system of devolved government in Kenya; creating Bomet County with Bomet town as the site of its County Assembly (168: National Council for Law Reporting, 2010). Sitting between the tea-growing hills to the north and the cattle-grazing plains to the south, centred on its bus station, and navigated by its four petrol stations, Bomet remains, like most towns in Kenya, more of a commercial than a residential centre. Bomet was chosen as a site for this research partly for its location in a highly populated region of the country, and so a focus area for the certified market, but also because Lighting Africa had hosted a

training session there in 2013 with a focus on the maintenance of products (Lighting Africa, 2013).

From my base at an electronic and electrical repair clinic on the main road, I began to discover the town during 'patrols' with one of my mentors,[66] with friends during our lunch breaks to various cafés, and alone in evening trips to bars. During these tours I spotted various references: leaflets, signboards and posters to some of the brands that had been on display in Dubai as well as several non-certified products too. In March 2016, I conducted a survey: I walked systematically around the town recording all the places and ways one could access solar products, which models were available, and at what price. In total there were 40 different points of sale. These were made up of 30 shops (selling from a roofed structure); 5 bank, co-operative, or microfinance institution schemes; 2 temporary stalls (plastic tables by the roadside); 2 roaming sales agents (with rucksacks); and 1 roaming hawker (also with rucksack) who dealt exclusively in solar products. There was also an occasional lorry-load of second-hand electronics that was displayed on heavily crowded tables again by the roadside.[67]

There were 56 different models of solar product available through these points of sale, representing 37 different brands: 12 certified, 25 non-certified. The brands available in Bomet informed which companies I sought to interview and observe in Nairobi. Although the share of sales points does not necessarily reflect the share of sales volumes, that there were more non-certified products available shows that in Bomet, like industry estimates for sub-Saharan Africa as a whole (12: Bloomberg New Energy Finance and Lighting Global, 2016), non-certified products represented a larger and growing share of the overall off-grid market against the certified ones. Similarly, that I found solar in 30 shops, only one of which belonged to a solar manufacturer (what is known as 'direct sales') does not necessarily mean that that is where most sales occur. Lighting Global for instance finds that sales agents and direct sales are the most common sales channels used with independent retail shops and importers coming lower down. Finance partnerships, bulk distribution, CSR and specialist distributors are lower still (23: Bloomberg New Energy Finance and Lighting Global, 2016).

[66] In lulls of work at the repair clinic (which were frequent) I would sometimes accompany Hesbon, one of the repairmen, on walks around town visiting various friends at their places of work, mainly roadside garages.

[67] The lorry that brought these second-hand electronics appeared twice in the 3 months I was in the town each time for two or three days. Speaking to nearby retailers on a return visit to the town in 2017 however I was told the lorry had not been in town for at least 12 months.

Beyond Bomet, in those villages where Shapps called for the race between companies the sales mix is different. Shop fronts in smaller market centres are less glossy and certified retailers are less common, even purveyors of electrical goods display a less focused offering selling solar products alongside food supplies. Toroche Enterprises in Siongiroi, a small trading centre 26km south-west of Bomet, is one example. In places like Siongiroi the direct sales of certified manufacturers, third party distributors and partnerships with finance providers have a diminished presence. It is in these villages that the non-certified market can be seen as most clearly riding off the success of the certified one – Toroche Enterprises uses the painting of a d.light S2 (fig. 2.3) to advertise its sale of solar lights, not just the d.light S2.[68]

Figure 2.3 *Toroche Enterprises* in Siongiroi, Bomet County with a painted d.light S2 on the shopfront. (Author's image, January 2016)

[68] In many parts of Kenya d.light has come to be used as shorthand for small solar lantern in a similar way that Hoover did for the vacuum cleaner. Regardless of whether the product they have or are selling is a d.light or a different brand users, retailers and repairmen alike all referred to off-grid solar products as d.lights or 'ma-d.lights' – a plural form borrowed from Swahili.

I did not spend much time in Siongiroi or other similar market centres around the county. Mainly passing through them on route to users' homes it became clear that most people travel to Bomet to purchase electronics where there is greater choice, better quality and lower prices. There are a few other areas of the market that did not feature in Bomet and so are not examined here. These are: bulk distribution, urban use, supermarket sales and online sales.[69] However, products purchased through these other channels are included where I encountered them in their journeys through homes (Chapter 4), repair clinics (Chapter 5) and company premises (Chapter 6). Further some products are bought in different countries (e.g. Somalia) and brought across borders as gifts for family members, these are similarly included when exploring the themes of breakdown, repair and disposal despite not having first-hand experience of the sales channel through which they were acquired.

At the retail level the certified market is most obviously distinguished by its branding. Certified actors invest in their brand through packaging, staff uniforms, building décor and promotional goods (like baseball caps) to be more visible than their certified competitors but also the non-certified 'brands'. Yet it is in sales training and consumer awareness campaigns that the market devices that underlie that aesthetic distinction are found. Certified actors run training to support the retail activities of independent retailers and sales agents that focuses exclusively on certified brands. These trainings stress the quality of certified products and emphasise the impacts the products can have. Consumer awareness events such as market days are used to further support the certified market using similar language of quality and impact. As part of the sales pitch consumers are taught how to use products, in order to shape usage and minimise breakdown from the manufacturer's perspective. Warranty is also mentioned in sales processes but repair and disposal are rarely raised. This section of the chapter argues that although sales processes are shaped by the quality standards and impact metrics it is from the point of retail that the certified and non-certified markets come to be merged and at times become indistinguishable.

[69] Bulk distribution refers to purchase by large agencies working in disaster or humanitarian relief or by large companies or employers as part of corporate social responsibility (CSR) schemes. Products are also found in urban contexts (particularly informal settlements), in supermarkets and online. Several brands and distributors for instance sell online to Western consumers using part of the profit on such sales to subsidise their operations in countries in the Global South (e.g. WakaWaka).

Certified companies brand their products, premises, staff, vehicles and other paraphernalia (such as umbrellas and baseball caps) in order to distinguish themselves from their certified competitors but also from the non-certified products which are often not branded at all. By August 2017, M-Kopa had even begun branding buildings around the country that do not sell their products; the wallspace acting as a billboard of sorts. Returning to Bomet in August 2017 after a year away from the town the presence of the certified market was even more prominent. As the minibus I was travelling climbed the final hill up to the town an advert came on over the radio for M-Kopa. Then when the minibus turned the final corner in to the town centre I noticed a new M-Kopa sign by the side of the road (it is common in Kenya for companies to place signs for their shops at the entry/exit to towns advertising their presence and crucially describing their specific location). And then when alighting at the bus station I saw a series of parasols branded by certified brand SunKing shading the roadside vegetable sellers who ironically light up their daily produce at night with rival brand d.light S2s (or non-certified copies thereof). This inundation of new indicators of the certified market only continued when that afternoon I spotted a shiny new shop out the back of the bus station (fig. 2.4):

Figure 2.4 The new Greenlight Planet shop in Bomet near the back of the bus station (Author's image, August 2017)

It was a branch of Greenlight Planet (the manufacturer of the SunKing products and parasols), who, with the introduction of their own home system, and its in-built mobile payment system, EasyBuy, had in the intervening year begun to do their own direct sales, having previously distributed their product through third party distributors. This growth in the presence of certified symbols around Bomet reflects the continued growth of the market in the time I was away. However, this proliferation of branding through items with their name on does not mean that brand awareness or loyalty had become any more prominent in the intervening year. The use of badged 'freebies' is a popular marketing tactic in Kenya connected to the roadshow model where waiting crowds are eager to come away with any giveaways. This is especially true for M-Kopa whose branding is in the national colours of green, red and black, partly thanks to its close connection to dominant telecommunications company, Safaricom who also use the green, red and black of the Kenyan flag to profitable effect.

One perhaps unintended consequence of the branding efforts of certified actors is that without the resources, networks or possibly the interest in replicating the marketing and advertising strategies of certified manufacturers and distributors or becoming certified themselves, non-certified manufacturers increasingly mimic the form, colour and packaging of the most successful products in a bid to increase their sales. The similarities in product and package design allow the non-certified products to benefit from the awareness and policy campaigns of Lighting Global, GOGLA and others without actually being present at the sales training events or on the lorries at market days: an example of when "intentional plans" and the "unacknowledged social world" collide (276: Ferguson, 1994). The d.light S2 being one of the earlier and most successful models has been a particular target of this (see fig. 2.5).

Figure 2.5 An unbranded product that looks exactly like the best-selling d.light S2 (Author's image, September 2015)

One response to these imitations at the retail level has been in training of sales agents to distinguish between certified and non-certified products. The GIZ-SNV EnDev programme recruits and trains 'entrepreneurs' to launch themselves as mobile sales agents for certified brands. These trainings cover items such as how solar works, what products are available, sales techniques and troubleshooting. SNV or GIZ, who split their responsibilities in the country into east (SNV) and west (GIZ), invite certified manufacturers and distributors to come and pitch their products at these trainings. In interviews with representatives of both organisations and at a GIZ training day I attended in Eldoret, in the Rift Valley, the programme's product neutrality was repeatedly emphasised. But this neutrality is only among certified brands, and so, taking a wider lens could equally be seen as a bias.

The EnDev programme also contains a consumer awareness element where certified companies are invited to attend markets around the country and promote their products at an EnDev stand. With such effort going in to the sales process for certified products it often felt to me that certified products are sold *to* users rather than bought *by*

them. When I suggested this to one interviewee who worked for certified brand, One Degree Solar he told me:

> I really like your point about how you said people feel, it feels that people have been sold solar lights, and if you actually look at the marketing and the rationale and these co-founders of the companies it makes sense. It's not, it wasn't an African that went, or an Indian that went 'we use these kerosene things and they're bad'. It was a bunch of Oxford and Stanford and, you know, educated… I'm not saying that's wrong, but I feel like your point about people being sold solar lights is right.

Despite the internationalised efforts by the certified community and the increasing adoption of those international market devices within domestic regimes of governance, in smaller market centres the two markets are less discernible. Such entanglement is reminiscent of colonial irrigation engineers and Nehruvian development planners' attempts to manage waste in India. Geographers and Gidwani and Reddy have argued that the planners "Comtean desire to reduce development to a technical problem" was "constantly thwarted" by the assemblage within which they were operating (1634: Gidwani and Reddy, 2011). In Kenya, the visual distinctions of shop fronts and sales channels come even more undone when one moves to the homes where certified and non-certified products are used alongside each other.

Merging markets

There are two off-grid solar markets operating in Kenya today: certified and non-certified. The two markets are distinguished by their relationship to two key market devices: the Lighting Global quality standards and the GOGLA impact metrics. The devices appear implicitly in a promotional video from certified company d.light design as described by Cross:

> d.light design CEO Sam Goldman stands at a bench next to component parts, plastic cases and tools.[70] In the first half of the film, he picks up a Nova S200 prototype and describes its physical, material attributes, its battery length, its brightness and its charging time. In the second half of the film, he lists the range of potential benefits that this light could have for users, emphasizing that it can help people to study and work at night, cleanly and safely. (376: Cross, 2013)

[70] Goldman was, at the time of writing, president of d.light design. Goldman was also, like the individuals met in Chapter 1, a Peace Corps volunteer.

The “material attributes” of the first half of the film are captured in the quality standards, while the “potential benefits” discussed in second half of the film are the basis of the impact metrics. Together they facilitate access to certain spaces, organisations and sources of funding and investment.

The typology of certified-non-certified is useful for keeping the quality standards to the fore in later analysis and also acts as a reminder of one community keeping out another based on a documentation process. The chapter has shown how the certified market, the focus of the rest of this thesis, focuses on the material qualities of the product at the neglect of its interactions with other human, animal and environmental actors all of which, as the next chapter will show, can cause or be involved in breakdowns in the assemblage. This concluding section first describes the consequences of the divide between the two markets for the themes of the thesis: breakdown, repair and disposal. It closes by indicating how that division may change in the future.

The underlying driver of the extensive work done by certified actors is to increase product sales. And, as Bhattacharya found in Delhi’s Mayapuri market, “alternative chains of circulation” (50: Bhattacharya, 2018) such as those found in the non-certified market can undermine those sales and so consumption. Repair and reuse sit in conflict with standardisation and predictability upon which the certified market depends. The focus on new product sales also neglects what happens when products break down. While the quality standards mean that certified products generally last longer than the non-certified ones (Lighting Global, 2018d), they are not invincible, they too will break down. And as all the benefits tracked by the impact metrics are tied to the functionality of the product; when the product breaks down these benefits and claims are undone. So if breakdown is present on both sides of the divide, then what happens in response?

The certified market through closer connections between user and manufacturer and ongoing relationships post-sale through PAYG models may offer opportunities for repair. However, the focus on creating a market, improving the regulatory environment and increasing consumer demand limits this. The non-certified market on the other hand offers a greater opportunity for entry from local repair. Although there is no provision for repair by non-certified manufacturers there is equally no barrier to their integration to existing repair networks. In places like Siongiroi and Bomet, generations of other electronics found on the same shelves of retailers in Bomet or of the wholesalers I visited in Deira have been serviced and repaired in independent repair clinics (see Chapter 5).

Finally, in terms of disposal the same trade-off is identified: the greater presence of certified actors makes product take-back (the first step of any waste management or recycling process) possible and branding makes identifying producers possible and so holding them to account. Although there is increasing recognition among certified actors of the need for adequate waste management the market devices in their current guise largely absolve certified actors of any responsibility. None of the traders I spoke to in Satellite Market were bothered by waste either and the looser, discrete, and transactional links and longer chains of their non-certified market make it harder to hold those involved to account over the waste their products become. However, that same openness could make for easier integration into existing waste streams and markets with waste workers able to collect, buy up and sell on constituent materials.

The relationship between the two markets is changing however. In Dubai the non-certified market was referred to in terms of counterfeits and copycats (4: GOGLA and IFC, 2015) yet just over two years later at the next gathering of the certified industry in Hong Kong the language had shifted to become affiliate and non-affiliate – less confrontational, more inviting terminology perhaps. The change in language could also be a reflection of, as admitted in recent certified market reports (12: Bloomberg New Energy Finance and Lighting Global, 2016; 1: Dalberg Advisors and Lighting Global, 2018), the sizeable, majority market share of non-certified products in many markets. Affiliate also reflecting a greater community of adherence now, recognising more than the standards alone but other devices such as the impact metrics as features of the market. The location of the 2018 conference, right next to China, could also symbolise the merging of the two markets, demonstrating greater acknowledgement of the non-certified by the certified community. Such changes are not necessarily surprising however. Granovetter and McGuire write for instance that

> Industries are constantly re-negotiated, re-framed and re-mobilized in response to their environment. (167: Granovetter and McGuire, 1998)

And in these processes of re-calibrating market devices are re-made too. Unlike more rigid rules,

> The ways in which market devices are tinkered with, adjusted and calibrated affect the ways in which persons and things are translated into calculative and calculable beings. (5: Muniesa et al., 2007)

Another change in the certified market has been the growing attention given to the waste produced by the industry. Despite GOGLA and the IFC having held a workshop on the topic in 2013 (GOGLA and IFC, 2013) and the Sustainability Working Group at GOGLA having published an Industry Opinion on Lifecycle and Recycling in 2014 (GOGLA, 2014) Muhammad Yunus' opening acknowledgement in Dubai that

> one of the thing that I have been talking about that I don't feel very comfortable because er that's a battery which is not very friendly to the environment. So we need to er, replace that battery. We need environment-friendly battery.

passed largely under the radar. A separate session dedicated to "Environmental and Social Sustainability Across the Value Chain" meanwhile was attended by less than 10 people. Yet, two years later in Hong Kong, the equivalent session filled its assigned room with nearer to 50 people. Meanwhile industry elders DFID and USAID have recently funded research in to end-of-life topics. In 2016 DFID commissioned a report to look at the issue (Magalini et al., 2016). And in 2018 USAID launched a $1.8 million grant programme to finance innovation in the area (USAID, 2018). US and European investors are increasingly asking companies what their waste policy is and manufacturers are under pressure from third party distributors to offer a solution too whilst they themselves face rising stockpiles of faulty products in their offices, workshops and warehouses (see Chapter 6). Although there is no current move to incorporate these growing concerns in to either market device: the impact metrics or quality standards, there is an indication that waste and recycling could yet become another differentiating feature between the two markets with certified actors seeking to distinguish themselves from the non-certified crowd by putting in place responsible waste management systems for their products.[71]

What is already clear is that

> whether they might just help (in a minimalist, instrumental version) or force (in a maximalist, determinist version), devices do things. [Market devices] articulate actions: they act or they make others act. (Muniesa et al., 2007)

The next chapter looks at how the market devices influence actions and processes of breakdown.

[71] Thus far Lighting Global discussions of end-of-life concerns have been kept to a series of working papers on topics covering Battery Toxicity, Hazardous Substances and Repair (Lighting Global, 2012; Lighting Global, 2013; Lighting Global, 2016b; Lighting Global, 2017b).

Chapter Three

Breakdown and the gap that follows

Coming back from waste

At the end of the conference in Dubai, my supervisor and I saw the solar waste we had each spoken about on panels a few days prior:[72]

Figure 3.1 A scene in the exhibition hall after the 4th international Off-Grid Lighting Conference and Exhibition (Jamie Cross, October 2015)

As exhibitors packed up products and parts of products, that which they did not take away was either gifted to friends, colleagues, or researchers – my supervisor was given one - or left behind on floor of the exhibition hall. These display and demonstration products are generally functional but once used in pitches or meetings from the stands and sofas of the

[72] My supervisor, Dr Jamie Cross, spoke as part of a session on 'Technical Advances and Environmental Issues Related to Off-Grid Energy Systems' (3: GOGLA and IFC, 2015).

conference hall for the certified actors they can no longer be sold or sometimes even used again at future events. The products which were left behind (fig. 3.1) were most likely disposed of into Dubai's wastestreams, if not first siphoned off by the workers tasked with clearing the hall. Despite for the most part still being functional and rarely materially damaged, in the act of leaving them, relative to the certified actors and their representatives at the conference the products became waste. Yet what was waste to the exhibitors becomes something else to the exhibition hall workers or those who work in Dubai's wider waste economy – a new relationship is formed. Such relationships are the focus of this chapter.

The lifespan of the display products that my supervisor and I saw was nearer to the 3 days of the conference than the 3 to 5 years advertised lifespan. Such (functional) display products are not typically what comes to mind when one thinks of waste electronics. Instead, the terms e-waste or end-of-life electronics more typically conjure images of urban dumps of consolidated computer screens and circuitboards, of child labour and polluting practices of informal recycling. This visual distinction prompts a need for an alternative term that can capture both the functional display products of Dubai as well as those in Kenya that, not functioning, may appear more typically as waste.

Aside from misleading visual connotations the analytical value of 'end-of-life' (EoL) is also limited. The term is too singular for the various things that can cause an object's life to end – a battery fault or a conference closing – end*s* of life. Nor does the term give any indication as to how long that life has been – 3 days or 3 years. The term is similarly ill-equipped to account for products that may have had more than one life (through repair, resale or gifting) - end-of-*one*-life. Thinking in terms of product lifespans or –times also offers little indication of where that waste product might be, in whose possession and in what condition. Adapting the EoL concept to account for these dynamics however would require agreement over the cause of that life-ending, when it ended and indeed whether its life has ended. None of which are guaranteed given that, as the old axiom goes, "one man's trash is another man's treasure".

That waste is regarded differently by different people at different times is broadly established in the growing area of discard studies (which stretches across anthropology, geography, philosophy and sociology). Despite continuing disagreements over what waste is (see Gille, 2007), there is broad agreement on what it is not. Academia and waste management practitioners share a general consensus that waste cannot be defined

according to any physical attribute but must instead account for the human-material relationships surrounding an object. Both the EU and UN place the relationship between an electronic product and its 'owner' at the centre of their definitions of electronic waste (e-waste) which, containing a battery and circuitry, discarded solar products qualify as (EU, 2012; UNU, 2018). Assemblage thinking helps keep such relationships and differing perspectives in view when analysing waste.

Waste, or discard, scholars also dispute waste as a consistent category (4: Goldstein, 2012). Social historian Susan Strasser, for instance, argues that waste is a dynamic category that things can move in and out of: "trash" Strasser claims "is created by sorting" (5: Strasser, 1999). While sociologist Kevin Hetherington points to a similar dynamism writing that:

> Waste suggests too final a singular act of closure, one that does not actually occur in practice. (159: Hetherington, 2004)

Instead Hetherington stresses the potential of rubbish to return from the state of being 'rubbish' to being something else.

Not only is waste not only found at 'the end' (not just in dumps) but waste itself might not be the end for an object. Despite a lingering tendency in capitalist societies and industrial economic processes to the contrary to see waste as something of an inevitable end point or by-product (4: Goldstein, 2012), the equation of end-of-life with waste has been challenged in waste scholarship (Cross and Murray, 2018). That products can be disposed of before use, at times before sale even, means existing approaches to e-waste, that concentrate on waste post-consumption are missing volumes, flows and sites from their studies. This falls within a broader critique from discard studies of the focus on consumer behaviour where waste volumes are minimal versus the discards produced in manufacture, at sites of resource extraction or through industrial processes where volumes are magnitudes higher (see Lepawsky, 2018b). The downstream focus on post-consumption practices has also been criticised for diverting attention away from product design (see Lepawsky, 2018a).

E-waste and end-of-life are not helpful because they suggest a finality and a permanence that the one example from the conference floor in Dubai already problematises. So if not using e-waste or end-of-life (or for that matter rubbish, trash, junk or garbage) how can we refer to solar products that are out-of-use? Having broken down existing terms and discussed their limits, this chapter and the rest of the thesis, uses

'breakdown' to capture the various disagreements, disconnections and discards that appear when examining solar products which are out-of-use. Breakdown suggests less permanence than waste; it can be undone. They can occur at any point. Breakdowns occur in disconnects between actors within the assemblage, when different perspectives and positions lead to different conclusions and actions. These breakdowns can be between the user and the designer, the conference participant and the researcher or countless other combinations including with inanimate and non-human actors.

Aside from terms in academia and industry a whole series of words came out of my fieldwork to refer to products that were not able to be, or no longer being used. These were: fault, failure, issue, problem, worn, fatigue, weak, damage, return and breakages. Fault was used by company representatives in interviews to refer to a non-functioning product as a result of a manufacturing failure and so is too limited for this discussion. Certified actors also speak of 'product failures' to cover the same materially deficient or performance-deficient products. Problem or issue are not used because they locate the cause or reason for the product's out-of-use status in or on the product itself rather than allowing for the possibility of it being located elsewhere in the assemblage. Other terms like worn, fatigue or damage are again too materially-minded to be used in this analysis. Talking of returned products is too tied to company after-sales and warranty processes, which do not cover all products taken out of or denied use. Breakage is not used because this is an act, or action, which suggests too singular or momentary a phenomenon for the examples below. This chapter needs a term that can cover functioning and failed products after a material change *as well as* those products that are materially unchanged. It needs a term that allows for the possibility of something happening in more than one place within the assemblage at one time, or perhaps extended through time as well.

Although there is an ethical argument in favour of adopting the terms used by those closest to the object of study: the solar product, it is more helpful in this study to take an external term - breakdown - in order to capture the disagreements that run central to understandings of and responses to times and moments when solar products are no longer in use. Only one interviewee used 'breakdown' and nor did it come up in the survey or during observations. The term breakdown *is* used occasionally in repair studies. Danielle Rosner and Morgan Ames (2014) for instance use it in their comparative study of the One Laptop Per Child programme in Paraguay and a Fixit Clinic in the USA, arguing that breakdown is produced through use and is collaboratively defined, often in the repair.

Jérôme Denis and David Pontille (2017) meanwhile challenge the traditional view of breakdown as a "univocal event" and use the diversity of maintenance practices around cars to argue that it is better seen as a "relational phenomenon" (16: Denis and Pontille, 2017). Cynthia Colmellere (2015) through her ethnography in a pharmaceutical plant recognises breakdowns as being both social and material and also as being moments of opportunity as much as of conflict. Although Steve Jackson and Laewoo Kang (2014) use the term, frequently prefixed with "technological", in their write-up of a collaboration with artists in New York, they do not specify what they mean by the word.

The chapter shows that the certified market's overly material understanding of the solar product, manifested in the quality standards, extends in to its understanding of breakdown. Neglecting, or not recognising, the surrounding relationships of the wider solar assemblage means the certified actor can only understand breakdown in terms of materiality and not in terms of relations between actors. This material understanding of breakdown leads certified actors to view breakdown as binary: broken (below the standards) or not broken (at or above the standards). Users, however, have a less discrete understanding of breakdown, talking instead of products lighting for *less* time or having to charge for *more* time. These divergent understandings of breakdown are important for later chapters concerning responses to breakdown and being able to capture the equally divergent forms those responses can take.

I was not present at any moments when breakdowns presented themselves during fieldwork in Kenya so the data drawn on in this chapter comes from a survey of users asking retrospectively and/or hypothetically about problems they have had or imagine having with their solar product. The chapter also draws on conversations with, and observations of, repairmen and company representatives as they assess and reflect upon broken down products.

The chapter first defines more specifically what is meant by breakdown and explains its analytical value to this case. Discussion then turns to the various types of breakdowns encountered during fieldwork: those connected to product and business design, manufacture and transit; installation and payment systems; theft and usage; force and impact; dirt and dust; and water and heat. The chapter concludes that breakdowns in the assemblage are productive events as they shape the possible responses that are available to it.

Breakdowns in relationships

Breakdown is inevitable. What is unknown in advance is where, when, why, in whose hands and in what form that breakdown will occur. Some breakdowns are external to the material product i.e. when a product (or parts of one) are taken out of, or denied, use independent of their functionality such as the display products in Dubai. While others are the result of physical changes on or within the product that affect the product's functionality i.e. a cable becomes torn or a casing is cracked (fig. 3.2).

Figure 3.2 A heavily damaged d.light S2 that Purity's brother found in a bush while playing near their house (Author's image, March 2016)

Understanding breakdown in terms of relations within the assemblage allows us to see that it is relations that make waste not material states. This section of the chapter further

explains how breakdown is understood in the context of the solar assemblage and how the term in turn both helps understand the various types of breakdowns *and* responses to breakdown encountered during fieldwork.

One broken down product can look very different from other broken down products. Some may show little visible sign of physical change, while others, hidden in cupboards or boxes for instance, may not be visible at all. Broken down products are also found in very different places and at very different times. Breakdowns occur in the warehouse, in the office, on the road, at home, in the shop, in the rubbish dump, or at the repair clinic. They can occur before sale, during sale, after sale, in use or after use. Breakdowns can also be triggered by very different actors, they can be triggered by manufacturers, distributors, trucks, logistics workers, sales agents, finance partners, motorbikes, users, repairmen, children (mainly boys), thieves, cows, rats, insects, rain, wind or even the Sun(!).

The range of breakdowns described in this chapter, some more materially dramatic than others, fits with Rosner and Ames' definition of breakdown not as a singular phenomenon but as a continuum (Rosner and Ames, 2014). Rather than think of breakdown as a binary state: fault versus no-fault, a continuum encourages thinking in terms of more to less broken down. Such a concept is similar to the idea of fluidity coined by de Laet and Mol in their work with the water pump in Zimbabwe. They found

> it is not clear *when* exactly the Pump stops acting, when it achieves its aims, and at which point it fails and falters. That is what we also mean to capture when we use the term *fluid*. (227: Laet and Mol, 2000).

The continuum of severity of breakdown can also be extended to understand breakdown not as a moment but instead as a process – a continuum of time. Breakdown is a process that can start earlier at moments of design when products are scripted with those qualities and impacts defined in the previous chapter which preclude certain actions and legitimate others, it is through the process of breakdown that those politics are revealed however and the disconnect becomes so untenable that the assemblage no longer functions to produce light or charge. Regardless of design scripts, any battery will run out of charge and so we might think of a period of use – the product's lifespan – as one continuous process of breakdown.

The breakdown process and its range of possible scenarios (in time, place and severity) makes it difficult at times to isolate a single cause of a breakdown. Especially

when different actors according to their position view, and so report it, differently. Generally, repairmen and company representatives identify users as the cause of breakdown, through ignorant or deliberate misuse. While users tend to blame the product itself or their children. These discrepancies are mirrored in the different views actors hold on whether or when something is waste or not.

The relational understanding of breakdown also helps draw attention to the social dynamics of breakdown particularly regarding gender and generation. It is often children that are involved in, or are blamed for breakdowns. There is a gender dimension to breakdown as well: men and boys cause more problems than women and girls who are more careful with their solar products. This is similar to Rosner and Ames' work where there appeared to be gender norms that allow boys "to be more rambunctious than girls" (323: Rosner and Ames, 2014) and so responsible for more breakdowns that their female peers. By turning attention to relationships around the product and not just looking at the material product itself these dimensions can be recognised.

Beyond capturing the multiple types and kinds of breakdown and their social dynamics that can occur, a relational understanding of breakdown also helps capture the multiple levels and scales on which it can occur. The scale of breakdown can be much bigger when a company collapses than when a single product falls from a user's roof for instance. When thinking of breakdown this way we can see large quantities of stock being written off by a company alongside the breakdown of a single product at home.

There is a degree of difference in the types of breakdowns that affect the three product categories subsumed in what this thesis calls the 'off-grid solar product': solar home systems (SHSs), pico-solar products (PSPs) and solar lanterns. Issues such as leaving a product out in the rain, placing it near a flame, or it falling under the feet of an animal pertain more to the solar lantern than the other two product types. Theft meanwhile is unlikely to occur of a whole SHS but more likely just the panel, whereas on a solar lantern where the panel is integrated in to the unit then the whole product may be stolen. These differences however are another useful feature of the relational understanding of breakdown whereby it allows for comparison and generalisation across the categories despite their material differences. Breakdown helps compare disconnects within the assemblage even when they may manifest themselves in different ways.

Types of breakdowns

Breakdowns mean a product (or parts of one) are taken out of, or denied, use. This section of the chapter describes ten types of breakdown, those relating to: design, manufacture, transit, installation, force and impact, dirt and dust, water and heat, under/over-usage, theft and business decisions. Although addressed discretely here many of these types of breakdown overlap.

Although a breakdown may not become apparent until it is in the hands or house of the user the process of breakdown can begin at the design stage. It is not a question of material fragility because as the previous chapter established the material strength of these products is the focus of the certified actors, instead the fragilities found in the solar assemblage exist in communication between the user and the designer and the retailer. Martin, a designer at Greenlight Planet, talking about rubber inserts that hold their SunKing product stands in to the main light-body, told me for instance that despite the company's best design efforts and "all kinds of pulling and damaging test on it" in the design process, once the product is in the field the rubber inserts, that keep the stand steady, can still fall out. In our interview in September 2016 Martin told me that "people may treat the lamp er with more violence sometimes." There are at least two breakdowns to observe here: one is the user's "violence", the other is the manufacturer creating a rubber insert, known as a 'pushing' that by Martin's own admission "is not hard enough". Although Martin recognised that no matter what Greenlight Planet do to make their products strong enough "people could've even break rocks.". Martin was conceding, in other words, that breakdown is inevitable. Because the pushing is not a common feature across different product designs there is no requirement of its strength nor test of the repeated removal and re-attachment of the stand that causes this issue in the quality standards. The same is true for the repeated bending and flexing of rubber flaps that cover the ports on other Greenlight Planet products. During a day observing the repair operation at SunnyMoney (who distribute Greenlight Planet products), George the technician there, and I saw multiple products missing their rubber inserts and flaps. Design then, even when aware of the characteristics of later usage, can begin the process that will manifest itself in use. It is also in design that products are designed to be portable for easy installation or use in multiple places yet this feature leads them to be susceptible to theft and falls, both types of breakdown that are discussed below.

Manufacture(r) breakdowns, although so named, are also not normally discovered until the product is already in the hands of the user. This group of breakdowns covers those products which do not meet the performance expected (as certified in the quality standards) due to something that occurs during the manufacturing process. While manufacture(r) faults can affect any part of the solar product the most common point of failure is the battery. Gijs, Chief Operating Officer for Africa at Barefoot Power, told me, as did several other interviewees, that the battery is the most vulnerable component of the solar product or system:

> …of course, and I'm sure you're aware of this, the weakest point in the system generally speaking is the battery, it's not the controller, it's not the LEDs, it's not the solar panel, it's the battery.

Indeed, when watching SunnyMoney's sales operation in 2014, Victor, a sales representative there, told me of one instance in Kitale (in the west of the country) the previous year when a "manufacturer defect" in the batteries of the products they were distributing had affected around 5,000 products. The replacement of which "gave us a headache" Victor told me, not to mention the damage it did to consumer trust, solar's reputation and the reputation of SunnyMoney. I experienced my own manufacturer breakdown, on a different scale, in the first weeks of fieldwork in Bomet when I bought a One Degree Solar Bright 1 to read by at night only to watch its brightness fade noticeably from day one. On my return to the town in the summer of 2017 I bought a Sunlar SK-R02 whose charge lasted a similarly short period of time.

In David's experience at Faulu (a microfinance institution who after initial partnerships with suppliers spun out a solar business), however, 10% of manufacture(r) problems were not to do with the battery but instead originated in other components: the panel, cables or the lights themselves. Indeed, after battery-related issues such as charging and a dimming light, problems with the switch were the next most frequently reported problem in the survey: 17 of the 262 users spoken to had had a problem with the switch on their product. And while shadowing Amos, a technician at d.light, in December 2016 he told me that the company had previously had problems with the LED boards in its torches coming loose so they changed the manufacturing process to put a glue around the head of the torch in order to fix the boards in place.

Other products might not make it in to use to even discover these manufacturing issues with batteries, switches or LEDs however. This is because some products experience

a material breakdown during transit**.** I witnessed one example in September 2016 at a company warehouse off Mombasa Road in south-east Nairobi. Wearing our high-visibility waistcoats, Julius, technical manager at the company led me down an aisle at the far end of which we discovered a pile of boxes that had obviously fallen. The boxes were all jumbled and squashed. Julius asked one of his team what had happened. But without waiting for an answer he began to climb up on to these boxes to assess the damage. Julius seemed a bit riled when Ken (his team leader) suggested the damage might have occurred in the container during transport. Julius dismissed this explaining that these boxes had come by plane and such things cannot happen in a plane. Having climbed down off the pile Julius told his staff to bring two guys in to sort it all out the next day to resolve the situation. Julius was annoyed because these boxes had spare parts in, including some new and particularly expensive soldering irons that would go out to service centres that were to be set up in early 2017. Later, in the taxi back to town, Julius told me that the boxes that fell had not been planned well and were not on proper racks. He told me that 'casuals' like the two guys who were to be brought in the next day are sometimes hired to arrange the boxes but sometimes: "They just decide to throw everything", maybe because they are rushing for lunch.[73]

I saw another instance of transit-related breakdown in December 2016 when I visited the warehouse of d.light further down on Mombasa Road. Wilson, the workshop manager there, was giving me a tour when I noticed a box with a label on top that read: 'G4S ACCIDENT":

[73] 'Casuals' or day labourers are used by several of the certified companies for one-off work assignments such as moving boxes or testing products. This is discussed in more detail in Chapter 6.

Figure 3.3 Boxes from a road accident sit in the d.light warehouse (Author's image, December 2016)

I asked Wilson what these, rather-squashed looking boxes were for, what the accident referred to. He explained that a couple of months earlier a G4S vehicle (d.light's logistics partner) was involved in a road accident while driving stock out west. The driver and colleague in the vehicle died at the scene. The stock they were carrying was damaged in the crash. Wilson told me that the managing director of d.light took the financial blow for this damaged stock, it was not, as would normally be the case, billed to G4S.[74] One notes that in both examples the fault, or at least the blame, lay with the logistics partner: Spedag and G4S, an actor that could easily be overlooked if one looks only at breakdowns occurring in moments and sites of use.

In both these instances of transit-related breakdown the stock was not all completely damaged. However, because the company could not guarantee it met the standards, it could no longer be used. It is not only in this pre-sale phase of a product's life that movement is important. Before starting the research for this PhD I worked for a solar company in Kenya and Uganda. On multiple occasions I saw our own company motorbikes topple over when overloaded with products on the back. Rough roads, not-always-fully-

[74] G4S is the contemporary name for what was formerly Securicor, the company with whom Harold Burris had had a close affiliation to in the 1980s (see Chapter 1).

serviced motorbikes and unlicensed drivers mean motorbike slips and falls are a relatively common occurrence. And when I visited survey respondent Dorcus at home in Nyange, Bungoma County in May 2016 she told me how she had sent a light she had bought from SunnyMoney on a motorbike taxi back to the school to get checked only for the motorbike to fall and further damage the product.

Even after navigating the rough and tumble of the warehouse and road networks there is still a chance of breakdown when a product is set up in the home. Although these solar products need little in the way of installation (unlike the older battery-based systems where installation, particularly system-sizing, was vital) users still require instruction on how to use their new solar lantern, or, in the case of solar home systems, where to place the battery, panel and cables around the home. Jaki, who previously oversaw the Kenya Tea Development Agency (KTDA)'s partnership with Barefoot Power, for instance, told me:

> a lot of people will say that their solar lighting products aren't working but it's because they nailed them in wrong.

Ironically Jaki suggested this was because the tea farmers would "see a product, see how simple it is to install and decide to install for themselves" but then puncture a cable in the process of nailing it in to a wooden beam in their house.

Installation is not necessarily a one-off event however. Huashan, the founder of Omnivoltaic (another certified manufacturer), referred to the placing of the panel as a "daily installation". Many users, fearing theft, high winds or playing children, only put their products or panels out to charge when they can stay nearby. This recurrent 'installation' was the cause of breakdown for several interviewees as it could lead to cables becoming loose or products, or parts of products, being dropped. Gijs, at Barefoot Power, mentioned how children, not quite tall enough, could drop panels when attempting to put them on the roof.

Loose cables and dropped products also fall under the group of breakdowns caused by force and impact. Force can be applied to a solar product in two ways: accidentally, as in the transit examples above, or routinely, perhaps through pulling a panel off the roof by its cable in the "daily installation". Accidental force is usually a fall from a roof or motorbike, or someone or even some*thing* stepping on to the product, or part of it. This accidental category includes incidents when a panel is blown off a roof as was described to me when I visited one home just outside of Bomet, at the edge of the local airstrip. Or when a child knocks or stands on a product as happened to Panai, another survey respondent, in Narok

County. While for John, also a survey respondent, in Nandi County it was a cow that stood on one of the seven d.lights he had bought from SunnyMoney. It is not always cows or children that are to blame however: Eric, from the Equity Bank Foundation, for instance spoke of cables being eaten by rats during the foundation's partnership with Orb Energy. While Huashan at Omnivoltaic also spoke to me of rodent-caused breakdowns.

One part of the Lighting Global quality standards requires that products should withstand a drop test from a height of 1m on to concrete on six sides of the product (3: Lighting Global, 2017a). While this would protect from falls off stool and chairs on which users often charge products and are normally below 1m in height (fig. 3.4), roofs, hedges and water tanks where I was also shown products are charged (fig. 3.5) are higher than this.

Figure 3.4 An unbranded pull-up lantern and a ST. Light charging on a stool outside Martin's house near Bomet (Author's image, March 2016)

Figure 3.5 A d.light S2 charging on a water tank outside Christie's house near Bomet (Author's image, March 2016)

Admittedly some of these would be falling on to dirt, grass, or carpet rather than concrete and so are perhaps protected in that sense. Meanwhile the strain relief test of cables, also in the 'Quality and Durability' measure of the standards, will help mitigate against teething rats.

In addition to these accidental impacts, routine (or regular) force can also cause breakdown. Describing his idea of the "daily installation" for instance, Huashan told me that people "yank, they try to yank the product off the roof". In our interview over Skype in August 2016 Huashan also said that: "people simply use too much force to insert the USB". This was echoed by other interviewees who describe users pushing cables in too hard or in to the wrong place and so damaging the cable itself, the port in to which it is supposed to fit or both. Unlike accidental force, breakdowns as a result of routine force are often less immediate. Instead they might occur from repetitive use. Continual switching on and off of the switch for instance, might, over time, lead to that switch getting stuck – a reminder of breakdown as a process.

Many of Greenlight Planet's products have a rubber flap that covers the charging ports to connect both the panel and the mobile phone, however after repeatedly or for a long period of time being held or bent back, this can break off, exposing the ports and, like a stuck switch, allowing for the entry of dirt and dust into the inside of the product where it can interfere with connections on the circuit board.

While the quality standards specify the need for mechanism such as the switch and connectors to be "functional after 1000 cycles" (3: Lighting Global, 2017a) this does not cover the 'yanking' or 'force' that Huashan told me about. The standards do however address issues of dirt and dust through its ingress protection measures (2: Lighting Global, 2017a). And when I spoke to product designers, or to employees about their product design, ingress protection was a frequently prominent consideration. Huashan, speaking from Hong Kong, told me:

> any minute little ant crawl into your product, your product's dead, the ant will die and their body will go basically dissolve into acid they will corrode your PCBs [printed circuit board]. And the ants like to get in to the product so we make sure no insect can get can get in the product.

In addition to dirt and dust, insects, can bring water and moisture in to the inside of a product, another thing the Lighting Global certification seeks to address in tying itself to

IEC International Protection Markings or IP codes (3: Lighting Global, 2017a). Products can also get wet from rain or having been dropped, or knocked, in to milk, the toilet, a pot in the kitchen or in a lake (solar lanterns are used by fishermen who work at night, particularly on Lake Victoria). Of these possible cases of liquid-damage, rain is the most common. A few voices from the 2015 survey illustrate this:

> "It was rained on and got spoiled."
> "One was rained on and refused to light. It's very dim."
> "It was left outside and got rained on."

This list could be continued: 12 of the 262 users spoken to spoke of rain having damaged their products. Water, like dust and dirt, is bad news for a product's internal circuitry. Martin at Greenlight Planet, as mentioned above, explained that the rubber cover that sometimes break offs through repeated use is there to protect the charging ports from water. It is "the first barrier for dust and water" he said. When I spent a day with George at SunnyMoney in Nairobi, in October 2016, we came across a product that had a piece of rope attached to it. From this George proceeded to narrate a story about how this user must be a fisherman and they must have dropped it in the lake one time while out fishing. This ability to tell a story about a user and what they have done to/with their product appears again in Chapter 6 looking at independent repair processes

One element that is not covered in the quality standards is for heat-related material breakdowns. This could be heat from a cooking fire, heat from the sun or heat that was internal to the product (usually the circuit board). In company offices, workshops and warehouses I regularly saw products where parts of the casing, strap or stand had melted. In the survey James in Nandi County, told Getrude (one of the research assistants) that his children had put the panel of one of his SunKing Eco products next to the fire in attempt to charge it and the panel had got "burnt". While Edwin also of Nandi County (north of Bomet) told Getrude that the top of his d.light S2 had cracked. Perhaps, he thought, because it was left in the sun for too long. One example Anthony, a software engineer at d.light, gave of this was users damaging their solar panels by charging them via the "fireplace". He said:

> they need to understand that you can't charge solar products via the heat place. But you see people who are in the rural folks, don't have this [understanding], they have a fireplace, they think they are placing next to the fire, no it's gonna charge.

One of the pioneers introduced in Chapter 1, Leo Blyth, reflected on how one product model in the early 2000s:

> started buckling underneath the African sun and actually snapped the connections inside because of the degree of buckle and heat so that was the first ever solar mobile phone chargers that were here, ... They sold thousands, they were in the newspaper and then the thousands started coming back and everyone was unhappy and yeah no one fixed them

When spending the day with Henry of Trony (a certified manufacturer) in August 2017 he also spoke heat and users fears that if they put their products on the thatched roof of their houses it could catch fire. The irony being that housefires are one risk associated with kerosene lanterns, against which the certified market defines itself. These different examples of the Sun being a threat despite it being the Sun that is the source of the power for these products are evidence of a further disconnect between actors. The Sun is central to the solar assemblage, hence the title of the assemblage, yet it can play different roles according to one's perspective. These mismatches in the assemblage are what lead to breakdowns.

One reason why these heat factors do not appear in the quality standards could be because for certified actors they fall more under the category of use, or in their parlance: mis-use, than anything concerning the performance of the technology itself. In our early morning interview at his desk, Ramin, vice-president for Africa at Orb Energy told me that:

> in 75% of the cases, any issue is not technical failure it's basically customer usage related either they're not charging it daily or are they are over-using the system, it's really how they use it

David, a former employee of Faulu (a microfinance institution who have spun out an off-grid solar business) for instance told me how Faulu found that:

> they [users] are trying to look around to trace what is what or they are trying to see if they can charge more phones or something, or trying to see if the product can power a radio, yeah issues like those

There are a few breakdowns occurring here. David is partly describing how users attach their panels (in this case) to other appliances or perhaps use the panel charging ports to charge mobile phones, practices which can damage internal circuitry or the external appliance. But the same description also highlights a breakdown in understanding between the user and designer or manufacturer: the user not necessarily understanding fully what

they have bought and the designer not fully providing what the user wants or needs. In another example, Anthony at d.light told me that users are rarely satisfied with a product and will ask themselves: "'what else can I charge with this thing?'" Answers to which might involve charging non-certified accessories such as pre-existing radios or connecting panels directly to mobile phones et cetera.

At the same time nearly every company representative I interviewed mentioned the issue of under-charging as causing problems**.** If it was not not charging the product for enough time it could be that users are charging it in the wrong way:

> they just put on, on the ground, where you find like there is shadows from the trees or from the other vegetation around. So at the end of the day the product is not charging properly

Or:

> they don't clean the panel so after some time there is like dust which accumulate on top of the panel

Or:

> where you insert the, the, the cable for the, to the battery maybe they've inserted it in the wrong way so they, it's been out in the sun, so they return it and say it's not charging but the thing was you really needed to have connected it properly

Both under- or over- use of the product will damage the battery and so lead to a breakdown that manifests itself in a dimmer light, a reduced run-time or the inability to hold charge in the battery. Again, there are at least two breakdowns occurring here: firstly, the lack of charge reaching the battery and secondly the disconnect between manufacturer and user. In another interviewee's words: "It's also because of simply people not listening" to that consumer training. The directionality here is important: it is not the manufacturer who is not listening or learning, from the user and their practices.

One type of breakdown that company representatives spoke of less was theft – despite its connection to under-charging and the issues that that can lead to. In their colourfully titled paper: *The Socio-Technical Barriers to Solar Home Systems (SHS) in Papua New Guinea: 'Choosing Pigs, Prostitutes, and Poker Chips over Panels'* Sovacool and colleagues find "an unusually high frequency of theft and vandalism of SHS" (1540: Sovacool et al., 2011). In my fieldwork there was not a high frequency of theft, only a couple of examples. In the twelve months after Noah and Francis (both of Bungoma County) first spoke to Lilian in the survey in 2015, for example, they each had had one of the panels to their SunKing products stolen. And when I visited Samuel also in Bungoma

County in 2016 he told me how a departing security guard had stolen the panel of a d.light S20 that belonged to the school where he taught.

The motives for panel and product thefts were not explained to me as "frivolous acts of revenge or vengeance" (1540: Sovacool et al., 2011) that Sovacool et al. found in Papua New Guinea but as being economically or personally motivated. When I asked Henry, one of Trony's two representatives in Kenya, why people steal panels he said they either take them to sell or they try and hook them up to a TV or:

> They go and modify it. They take negative and positive, they use on the radio. Ok. But they, some guys they think it is a something unique, ok? They don't have know-how, the use of the solar, they just steal, then they go at the end they get "Oh it has no use"

Regardless of the thief's motivations or what they then do with the panel later theft causes breakdown through the disappearance of the whole product or part of it.

More commonly reported than actual theft was the fear of theft. Julius at Greenlight Planet, for instance, told me that it is part of a culture in rural Kenya where theft is a common fear. Gijs also mentioned the risk in our interview:

> [in] some of the areas there is cases of theft and they put a solar panel on top of the roof and then the following evening they find that somebody has stolen it.

This fear can increase the chances of the breakdowns already described that come from placing products or panels in shaded or less optimal locations to limit visibility, not charging products regularly so they can be kept inside (and out of sight) or put on the ground (rather than the roof) exposing it to being knocked or stepped on by children and livestock, or repeatedly moving the panel/product in and out thereby increasing the risk of a fall or a loosened cable etc. For the purposes of this chapter however it is less important why or who is thieving and more that theft exists but more widely that the threat of theft is enough to influence behaviour and so contribute to breakdowns. There is also an irony in this as users often remark that the sign of light that a solar product can bring enhances the security of the household (Bisaga, 2016).

While theft is an old phenomenon in the solar assemblage the newer pay-as-you-go business models have introduced a whole new set of possible breakdowns. During days with Greenlight Planet and d.light much of the troubleshooting I observed and assisted with was concerned with the control units of SHSs through which payments are mediated. I was told that users do not always enter payment codes into the control unit keypads correctly

and that some try to bypass the payment system altogether. Other challenges for the functioning of these PAYG products are to ensure they are communicating properly with Nairobi and that they have adequate mobile signal to do so (for they work through GSM networks). Users of PAYG systems meanwhile regularly complain about credits (for a certain amount of charging time) not being uploaded or being lost. Similarly, the numbers on keypads can rub off through usage and labels on products containing important customer account or product reference numbers can peel away and fade through time, further complicating matters.

Aside from this sequence of breakdowns that can occur through the design, delivery and distribution of products there are business decisions which can contribute to breakdowns elsewhere and at times on a dramatically different scale. The display products described at the beginning of the chapter are an example, though a minor one. Two other examples where business decisions cause a breakdown are one, the introduction of a new product line meaning the previous one is discontinued and two, in 'writing off' stock that is just not selling. During our interview over lunch, for instance, David told me of one time in Faulu's early days in solar (ca. 2011) when:

> the market completely rejected the products, I think, we sold less than 30 or so. We bought products worth 1 million shillings, we didn't even return 30,000 [shillings] was on higher side, so we wrote off the entire stock.

I asked David what they then did with this materially un-touched but financially unviable stock:

> It's still at EcoSmart it must be in the stores somewhere.[75] It was never thrown away, it's still there somewhere, at least it was when I left.

The financial and human resources required to sell it would be a waste for them so rather than waste that, they wasted the material products. When I visited the EcoSmart store in September 2017 just over a year after meeting David and six years after the incident he described I did not see the stock he had been referring to. Stephen, who showed me round the workshop (a large cupboard of a room), had only started with EcoSmart in a finance and administration role in 2013 and so did not know what had become of the written off stock.

[75] EcoSmart was a spin out from Faulu's early partnerships with other manufacturers to source its own solar products directly.

When being given the tour of the d.light warehouse however I was shown a whole section of stock of a previous product generation that although functional would not and, according to a business decision, could not be sold. Although on a lower scale (100s rather than 1,000s of units) than in the warehouse, prototypes and marketing products in shops and offices of solar companies are another example of breakdown where functional products never reach use and so hold the potentiality of becoming waste.

The next, and final, section of this chapter discusses how breakdowns are formative: the type of breakdown, when and where it occurs do a lot to shape the possibilities for what can come afterwards and so whether or not the broken down product is repaired or disposed.

Breakdown as formative

The quality standards work to address some of the types of breakdown discussed above, namely: force and impact, dust and dirt, and moisture through the drop test, ingress protection and strain relief measures within the 'Quality and Durability' component. And out with the standards, company representatives spoke in interviews of their efforts to reduce problems arising from manufacture, installation and use. There did not appear however to be any conscious effort to reduce breakdowns through transit, theft or business decisions. This could be because they are relatively rare. Although falling under the company remit they will presumably still receive more attention from certified actors looking to minimise product failures and returns than do other types of breakdown. While the standards do a lot to protect against material breakdowns, their lack of attention paid to the surrounding relationships of the assemblage means they do little to address the more socially-created forms of breakdown: these might be the impact of a fall in transit from underpaid, casual labourers rushing to complete their work before lunch or precarious motorbike riders looking to maximise their returns on a single journey.

There are also other more macro, market-level breakdowns that the standards could not capture. The continued entry of non-certified products into the country could be viewed as a breakdown by many in the certified market. Or the fact that the labour-intensive dichotomy between certified and non-certified markets breaks down at some points of sale and especially in sites of use. Or that several companies have already closed down: Tough Stuff, SunnyMoney and One Degree Solar have each stopped operating in

Kenya, leaving behind a material legacy (as discussed in Chapter 1) of products, the company closure breaking down the relationship with their customers too.

The chapter then has demonstrated an immense variety of types of breakdown. If it is bad to be inside where it can get dusty, bad to be outside where it can get wet and bad to move it (portability) and un-plug it then threats of breakdown are everywhere. The ubiquity of breakdown should be taken as a reminder that breakdown is inevitable and more than that it is not exceptional. At some point, all solar products break down. Although this chapter has focused on examples of early breakdown (before the intended or advertised lifespan is over) general usage (even according to manufacturer-defined limits) also leads to breakdown. Even if the testing laboratory setting could be replicated, a battery will eventually reach the end of chemical reactions it can perform and stop holding or releasing charge. There is also the accumulation of dust and oxidation on circuitboards and charging ports that, in Houston's words, demonstrate the "slow temporal horizon of breakdown-through-being" (52: Houston, 2017). This kind of breakdown overwhelmingly occurs in rural homes, the main site of use which is where the thesis moves in the next chapter. But first, this concluding section recaps the chapter and discusses how processes of breakdown are also formative and influence later relationships within the assemblage.

This chapter introduced the term 'breakdown' to capture processes through which solar products stop or are prevented from functioning. Unlike the terminal or permanent connotations of words like waste and failure, breakdown suggests the possibility of being undone. When thought of as a continuum, the term helps capture a more dispersed and diverse set of phenomena than are typically associated with ideas of e-waste or end-of-life electronics. The term also turns attention away from the material product and towards its surrounding relationships, the assemblage. Breakdown allows the focus to move from less about what is built *in* to the products (materially) and more towards what is built *around* them (the assemblage).

At one end of the continuum there are the products that Faulu wrote off or those unopened in the d.light warehouse that would function perfectly well, and at the other there is John's d.light squashed by a cow. The breakdown continuum will be important when looking at user and independent repair practices (chapters 4 and 5) where a more graduated understanding of functionality exists versus the company setting (Chapter 6) where products are working or not, a reflection of their commitment to the standards: themselves a binary measure. The definition of breakdown developed here also allows for

a more differentiated understanding of the product where parts can break off, be lost and fall away which is important for the following chapters where discards appear as parts and bits rather than whole products.

In an influential discussion of disposal, sociologist Kevin Hetherington describes a gap between consumption and disposal, a sort of holding ground from which rubbish can sometimes return. This idea is compatible with breakdown. Breakdown creates a gap in the assemblage, between two previously related actors. A product waits in the gap until a new action forms a new relationship. This possibility to undo breakdown, for rubbish to return, in Hetherington's words (Hetherington, 2004), is already recognised by repair scholars Jackson and Kang, who describe processes of breakdown as "creative" (457: Jackson and Kang, 2014). Breakdowns are not just processes through which a relationship ends or a wire comes loose, rather they can be, and often are, productive. And so rather than think of a breakdown as the end it can equally be thought of as a beginning, ushering in a new phase for a given product in the potential for new or altered set of relationships.

The gap exists on several levels. It exists as the space where the product actually sits and waits. It also exists in actors' decision-making as users say they will do one thing and when the time comes they do another, or company representatives say a process works in this way yet in practice it works that way. The gap is the space between breakdown and response. It is spatial and temporal and it helps break linear understandings of the relationship between consumption and disposal. Fabian Echegaray and Francesca Hansstein (2017) call it the "intention-behaviour gap", while Garrath Wilson and colleagues talk of it as "hibernation" (Wilson et al., 2017). The concept is also compatible with Bhattacharya's analysis of a junkyard in the Mayapuri district of Delhi. Bhattacharya characterises the junkyard as a liminal space in which waste things sit until some labour or action gives them "a fresh lease of life" (48: Bhattacharya, 2018). The subsequent chapters go further however to gaps in multiple locations and forms. The liminal space in Kenya is shown to be more pervasive than the peripheral junkyard of Bhattacharya's study.

Breakdown moves products into the gap, responses to that breakdown, such as repair, move the product back from the gap and in to action again. Other responses can move it on and into new places performing new roles. There is no consistent figure as to how long or wide the gap is, broken down products leave or move on from it at different

times for different actors. It may be temporary or it may be forever and it may yet return to the gap again and again any number of times.

The ability of rubbish to return, for the breakdown to be undone, is dependent on the nature of that breakdown. The surrounding relationships and the way, time, place and in whose possession the product experiences breakdown shapes responses to it. It is through the process of breakdown that manufacturers, distributors, users and repairmen each form particular understandings of each other and the products. Users blame the product when after a few months the light dims. Independent repairmen blame users for causing problems and not always telling them the whole story. Meanwhile companies blame users for mis-using products when they try and charge 'too many' phones. Breakdown, like waste, is contested yet unlike that mass noun breakdown captures this very contest in its own meaning. The disagreements over what causes breakdown extend in to what responses are taken. In the company setting it is unlikely that the written off product will make its way in to use in a home or elsewhere, from the gap it will be disposed. But at the other end of the continuum other things can happen. Depending on the damage Panai's child caused to her S2 there are actions she can take to return to it to use. It is to these futures that Part II of the thesis attends, moving across three of the main locations where breakdowns occur: the home, the clinic and the company. Given that most breakdowns occur at home it is there that the thesis moves first. But first, an interlude.

Part II

Responding to breakdown

Interlude

Bricolage and its sediments

This interlude introduces two key ideas that run through the rest of the thesis: bricolage and sediments. In analysing how people repair the concept of bricolage is useful to see that despite different settings and motivations, repairs proceed in much the same fashion wherever they take place and whoever performs them. When looking at disposal practices there are again differences across each location (the home, the clinic and the company), particularly in scale and destination, but small amounts of waste were observed to fall away at every stage of repair and disposal in all three settings – that which falls away is referred to as sediments.

A French word, 'bricolage' is defined in a dictionary as meaning a manual, non-professional activity normally involving repair, installation or creation at home (Larousse, 2018). Although understood in subsequent chapters as creative and relating to repair, the bricolage being discussed here *is* found in professional contexts, *can* be outside of the home and is *not always* a solely manual activity. The definition of bricolage used here also draws from that proposed by famous French anthropologist Claude Lévi-Strauss to distinguish mythical thought from scientific thought. Rather than use it to distinguish between magic and science however, bricolage is used in this thesis to describe an approach to a problem and the actions in which that approach may manifest itself[76].

Lévi-Strauss outlines how the bricoleur – an individual who practices bricolage – thinks, and works, in contrast to the ingénieur. The bricoleur begins work from that which already exists and is at hand, any of which could be put in a different order or sequence and so change the outcome (Lévi-Strauss, 1994). The ingénieur on the other hand procures in advance the tools and materials they deem appropriate for a given task.

[76] The concept is used whilst recognising, if not resolving, the paradox highlighted by thinkers such as Indian historian, Dipesh Chakrabarty of using European ideas to interpret non-European practices. European intellectual thought, writes Chakrabarty, "is both indispensable and inadequate" (6: Chakrabarty, 2008) to capture or understand the subaltern experience.

Since Lévi-Strauss many others have worked with the concept. Of most relevance to this research are studies of drip irrigation systems (Benouniche et al., 2014), windmills (Garud and Karnøe, 2003), bottom-of-the-pyramid entrepreneurship (Linna, 2013) and wastework (Holt and Littlewood, 2017). Two of which are also based on fieldwork in Kenya: Linna (2013) and Holt and Littlewood (2017). Bhattacharya also uses the term when speaking of how waste things in the junkyard await "the craftsmanship of the bricolage" (48: Bhattacharya, 2018) in order to move on to a new life or purpose.

Using the term helps connect the thought and action involved in repair processes. Bricolage implies something more creative than repair, which, through its roots in the Latin *reparare*, can suggest the return or moving back to a previous state. Re*pair* can also imply a joining of two parts which, as the data and examples below will show, does not match with how repairs are thought of or enacted on the off-grid solar product in Kenya. Bricolage then keeps at the forefront the idea of a multiplicity of sources being drawn from and together, more like a collage. By using the term bricolage, the analysis can also still draw across three different locations where different languages were used by informants during fieldwork. The concept also helps begin to move discussion from the off-grid solar product, a heuristic, towards considering development thought more generally. If the micro-practices of repair are understood as bricolage, what might the implications be for the macro-project of repair that is international development? This question is returned to in the conclusion.

Working from existing sets and signs shows that repair is about remaking the relationships in the assemblage that give way during the process of breakdown. The argument of the thesis is that while the who, the why and the what of repair may vary across settings, as the cross-disciplinary field of repair studies makes clear, the how is consistent: all repair is bricolage and so all those who engage in it are bricoleurs. Despite differences in motivation, there are some commonalities across settings and sites of repair. Any repair starts with an object that has already been created and so any effort to restore some or all of that object's previous state requires working within some pre-defined limits. This process of starting with what is 'at hand', drawing on previous experiences and not seeking an ideal, pre-ordained or consistent outcome but simply one that works is remarkably similar to bricolage as laid out by Lévi-Strauss (1994). And like mythical thought's unending "ordering and re-ordering" (22: Lévi-Strauss, 1994) repair is never-ending. Fixes are temporary and re-breakdown is inevitable.

It is also inevitable that some things cannot be repaired and so must be dealt with in other ways.

Chapter Four

Repair and disposal at home

Routine repair

This chapter argues that repair occurs at home in two ways: through changing *how* the product is used (repairs of practice), and affecting physical changes to the product (material repairs). Drawing on the blossoming literature of 'repair studies' in anthropology, geography, sociology and science and technology studies (STS) the chapter suggests that the certified actor's attempts to limit users to use, and to exclude repair, runs counter to other studies that argue for repair as being an innate, irreducible human trait (McLellan, 2013; Spelman, 2003). However, unlike that literature's language of innovation and adaptation the examples provided in this chapter do not support a form of *créolisation* (43: Edgerton, 2008) or *jugaad* (Radjou et al., 2012) nor are user's actions evidence of anarchism (Sterling, 2016) or joy-inducing discoveries (McLellan, 2013) but instead they are more of an unexceptional, pragmatic response to breakdown.

Repairs of practice are those actions where the alteration is made not upon the product itself but in the surrounding manner of its use: when a panel is stolen a user may take their product to charge from the electricity grid. Material repairs are those actions where a physical alteration is made to the product: a user may use a small splinter of wood to prevent the switch from getting stuck under the casing of the product. Of these two types of repair, repairs of practice are the most common at home.

While users might recognise their material repairs as such: 'I fixed it' or 'I repaired it myself', so pragmatic are users' repairs of practice that they do not actually describe what they are doing as repair, indeed they do not give it any name. Users accept breakdowns at the less severe end of the continuum (a dimmer light or stolen panel), altering their routines almost automatically to accommodate the reduced or changed functionality of the product. This lack of a word to describe their actions supports the argument of this chapter that the acts are rather mundane and not, as some existing repair studies suggest, part of a broader intellectual or social project. Similar then to the term 'breakdown' used in Chapter 3, or 'certified' in Chapter 2, the terms 'material repair' and 'repair of practice' are more

analytic than emic. Also like breakdown the terms, within the framework of assemblage thinking, show the socio-material relationships that make possible the solar product and that these relationships can shift.

Although Spelman (2003) calls on researchers to recognise repair that does not involve the physical tools commonly associated with it (like spanners and screwdrivers) and Gregson and colleagues focus on the "routine, mundane work" (251: Gregson et al., 2009) of object maintenance there is scant coverage in the academic literature of, and so no terminology to describe, people's daily work on themselves to make an object work. The use of the phrase 'repair of practice' allows this chapter to explore how people adapt themselves and their use of an object in response to breakdown rather than alter or replace the object.

The chapter shows that repairs of practice are more common than material repairs. This is partly because repairs of practice are often an interim or temporary solution, users have adopted such, until the moment when the product moves further along the continuum and they can no longer support its breakdown. Or they enact the repair of practice while they wait, before the product moves on to another location like the independent repair clinic (Chapter 5) or the company repair process (Chapter 6). Although the material work of repair might happen more in those locations: the clinic and the company premises, the home remains a central part of the process affecting the work that happens in those places. Repairmen and technicians imagine how a breakdown occurred at home, and any prior responses to it, in the process of pursuing their own repairs.

Both types of repair do however share some characteristics with each other and with those observed at the clinic and company. Material repairs and those of practice both involve trial and error and the use of resources 'at-hand'. As a result, in both cases functionality is prioritised over aesthetics and, often temporary, their outcomes are inconsistent. These elements all point to repair as a form of bricolage.

Not having lived with users and only ever visiting for short periods (usually no more than two hours), I did not witness or perform repairs at home.[77] Similar to not having directly observed breakdown, the data presented in this chapter is from reported rather than observed repairs. The data drawn on largely comes from the survey of users but is also

[77] Having said that my acceptance of the reduced functionality of the two solar products I had bought in Bomet for night-time reading and note-taking could be interpreted as repairs of practice.

informed by interviews with and observations of independent repairmen as well as company-employed technicians. Self-reports are not without problems however. Reno writes, as Rathje and Murphy (2001) had recognised before him that: "self-reports are an unreliable way of gathering evidence of people's discard practices" (265: Reno, 2013). It is for this reason that in my fieldwork I sought to triangulate self-reports (acquired through the survey) with home visits. When visiting users at home, I asked them to walk me through what had happened; to show me on the product materially and demonstrate within the household spatially.

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In the survey it was difficult to clarify if people were talking of self-repair or taking for repair. Responses in the Excel sheet such as "I will look for someone to repair, or fix it" could mean either that the respondent was interchanging repair and fixing as verbs – they would look for someone else to get their product functioning again. Or the same response could mean that the user would first look for someone to repair it and failing that they would fix it themselves. Even a seemingly less ambiguous response like "I repaired it" could mean it was taken to a repairman for repair or that the respondent had repaired it themselves at home.

These doubts are only increased with the case of respondents such as Noah in Bungoma County who told Lilian that he himself was a *fundi* (repairman) blurring the boundaries between personal and professional. Others like Joseph said their son was a fundi and so earns his living from the repair work. While others still (like Daniel, Jane and Wilfred) spoke of their sons as being good or capable with electronic and electrical items. The landlord of Samuel who I visited in Sirisia, Bungoma County was also a fundi. It was not practical to re-call each respondent to clarify their meaning, nor to ask my three research assistants if they remembered, or indeed had ever understood, what exactly the respondent was referring to. The overlap of categories made deciding what data to draw from in writing this chapter a challenge at times.

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The chapter begins with a discussion of the imagined user, a category successfully created through the history, market devices and practices of certified actors. The second section looks at gender stereotypes that are held up in conversations and observations at home.

Men and boys are understood to be more reckless in their use of products but also more likely to attempt to fix them when broken down than women and girls. The subsequent two sections look at the two types of repair identified at home: repairs of practice and material repairs. Repairs of practice such as sharing panels or charging products from an electricity grid are shown to be the most common response to breakdown at home and often a precursor to later responses. Material repairs such as taping up a cable or using some wire or rope to tie a case together are less common and mainly for more severe breakdowns. The prevalence of repairs of practice over material repairs is the result of repairs at home being pragmatic. Then the chapter turns to look at other responses to breakdown these include playing, teaching, selling, burning, putting down the toilet, burying or throwing away. The chapter concludes that starting from waste, rather than what makes waste, misses both the gap and the range of things that can happen to a broken down solar product and the range of places it can move to from the gap; things and places that waste is not typically expected to be associated with.

Imagined users, imagined uses

Figure 4.1 A child studying by solar light in Zambia (Patrick Bentley/Solar Aid, Unknown date)

In this image we see a young boy studying by the light of a solar lantern (a d.light S2). The image is similar to one on a leaflet that I was shown by Julius as we drove back to his company's head office after the day down at the warehouse. Julius showed it to me with a degree of pride, himself excited by the new material that he was also seeing for the first time. On one side it listed the technical capacity of the product (a nod to the quality standards) and on the offer it showed a child studying by Greenlight Planet light (an illustration of the product's impact). The above image and the one on the leaflet Julius showed me are illustrative of the broader image of the off-grid solar industry in Kenya. Studious children, mud walls, and thatched roofs are common sights in such materials. Together with the market devices described in Chapter 2 they serve to present the user and the use of products in certain ways, in a certain light. Users are conscientious students, cooking mothers, or happy families found in living rooms or kitchens at night. Of course the selective use of images to sell goods is not unique to the off-grid solar industry. Nor is it only within energy access that the market is playing a role in international development (Prahalad, 2006). Their significance here is that they further contribute to market construction and shape how use is understood.

Although predominantly designed for domestic use, as in the above image, products might also find themselves in use at school, in a shop, or from a roadside stall (either balanced on an up-turned bucket, resting on a big stone, or hanging from a wooden kiosk structure). Products are also used as bike lights or for night fishing. Marketing materials have until recently however concentrated on the home and on its use there (as do the Impact metrics discussed in Chapter 2). Leaflets and presentations at industry conferences do not carry images of people carrying products to the toilet, such as Anthony at d.light told me was common in our interview. Nor do they feature those for whom solar is a back-up for the grid in power cuts, like the Glowstar had been in the early 2000s (see Chapter 1). Even the presentation of the home however is different from that I observed during fieldwork: in marketing images panels are on roofs not the ground, or stools, (both common practices).

This variance in places of use leads to a variety of users. Images like the one above (fig. 4.1) feature children and women prominently. They do not however include animals or insects that also interact with products (see Chapter 3). Rather than seeing the user as an individual it is more helpful to think of the user as a role. The user-role can be performed by different actors and often in addition to other roles. They could, for instance, also be a

sales agent, an electrical/electronic retailer, a repairman or a solar company employee. Other family members, visitors, researchers, and thieves all might also use the product during its lifetime. The company category of 'user': both that portrayed in marketing materials and that spoken of by technicians in company offices, workshops and warehouses, does however show some understanding of this diversity. There is for instance awareness of access to products and their distribution within households across generations (Jacobson, 2007) and especially across genders (Pachauri and Rao, 2013).

The image of the user comes with a certain understanding and definition of what use is or should be (i.e. the panel on the roof not the ground). This chapter is about how that representation shapes the events and actions that occur at home in response to product breakdown. This does not include repair. Repair is not the role of the user and the home is not allowed to be a site of repair. Historically kept outside of the products (Chapter 1) and more recently framed as beneficiaries by the market devices (Chapter 2) the chapter shows that despite the best efforts of certified actors (donors, funders, NGOs and companies) to the contrary, the user *is* a repairer and the home a site of repair.

Men and boys

One element of the imagined user that largely remained unchallenged in interviews and visits to users' homes were gender stereotypes. In company offices and workshops when discussing 'tampered' products or assessing products received back from 'the field' managers and technicians exclusively referred to users as men. This was especially true when material alterations had been made to the product in front of us. This fits with much of the repair studies literature: Gregson's handyman Barry (a man: Gregson, 2011), Willy the mechanic in Douglas Harper's North Country (a man: Harper, 1987), or Houston's phone hackers in Kampala (men: Houston, 2013). Beyond repair much has been written about the connections between gender and technology more broadly, specifically between men and machines (see Mellström, 2004). This work has shown how technology becomes the preserve of men and so integral to cultural and social identities of masculinity. However, women use technology too and the examples in this chapter, both material repairs and those of practice, seem to involve and include women as much as men.

Kenya is largely a patriarchal society (at least in the public sphere): business and politics are dominated by men and it is men who are more often seen in bars, cafes and on roadsides. This male dominance is only in enhanced in the domains of energy and

technology: all interviewees at solar companies were men and all repairmen and technicians I observed were male too. This is reflective of similar imbalances at international conferences such as those attended in Dubai and Hong Kong. Where women were better represented it tended to be in sessions on policy, finance and impact rather than technology.

These gender differences have been located in other studies of off-grid solar. In the case of a PLAN International project in Guatemala, for instance Nieuwenhout et al. (2001) found that

> [i]n spite of training, the users were not able to repair basic failures correctly; one reason was that training was not directed at the principal users, women. (462: Nieuwenhout et al., 2001)

There were examples in my fieldwork (see below) where women, without any apparent form of training pursued repair – particularly repairs of practice. This supports Spelman's work that when working with a broader definition of repair, one in non-typical spaces of repair and with non-typical repair tools, we can reveal other repair activities. Spelman locates women's affinity to repair by connecting it to care as other scholars have also done (Callén and Criado, 2016). And while women were not associated with repair in my fieldwork the association of them with care was common in both interviews and home visits. Steve Mukui, one of the survey respondents, for instance told me how his daughter looked after her SunKing Eco product very well and guarded it from the "carelessness" of her two brothers, whose own product had broken down.

More specific than men in general breaking and fixing things there was also generational angle that emerged in fieldwork. Boys were particularly spoken of, as Steve did, as the source of and solution to breakdown. During one home visit in Bungoma County I asked Kenneth, another survey respondent, why he had not taken a broken down solar product to the One Acre Fund (the social enterprise from whom his wife had bought it) who have a large and permanent presence in Bungoma town for repair or replacement: "Boys sometimes are creative...he wants to create something unique". He replied. So while some talk of children as causing problems, other survey respondents spoke of children, exclusively males, as the solution, the repairer. It would be difficult to say whether boys are more inquisitive and so knowledgeable or whether it is more accurate to say that boys in Kenya are allowed to be more inquisitive and so become knowledgeable regarding the

restoring of functionality to the same products that they may well have broken in the first place; sometimes a response to breakdown is to give the broken down product to a child.

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Through most of my fieldwork being a man was of great use to me. I am confident I would not have gained as much access to the repair clinics and workshops and warehouses explored in chapters 5 and 6, was I a woman of a similar age (mid-20s). Indications of this were the frequency of conversations, sometimes lengthy ones, about whether or not I had a girlfriend, was married or was looking for a Kenyan wife. At the repair clinic in particular, jokes were made at times at the expense of young women who came.

However, there were also occasions when my gender became problematic. One of these was after a home visit with Purity, a lady in her early 20s. Purity had brought an M-Kopa radio in to the clinic for repair and, as was my strategy, I then arranged to visit Purity at home to learn more about the biography of this particular product, its breakdown and its repair. However, after I had visited her at her family home I received a series of calls and text messages hoping to meet with me again. Although this enthusiasm was common with respondents of all genders and ages, it was made clear that future meetings with Purity were to be of a romantic nature. A second instance was when I went to visit Dorcus at home in Bungoma. Following this visit I received distressed calls from Dorcus whose neighbours, assuming she now 'had a *mzungu'* (white man) were asking her for money and favours. A third occasion when my gender created a problem was in a rumour, although little circulated, that I had been staying with a single woman in Kapkwen, a small centre up the road (west) of Bomet. This emerged from an evening visit I made to a home there at the beginning of my fieldwork when I was looking for a homestay to better inform this very chapter of the thesis about the dynamics, activities and actions at home. I only became aware of this on a return visit to Bomet in August 2017, over a year after having last been in the town.

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Repair of practice

When Pamela's SunKing Mobile stopped charging at her home in Migori County, near the border with Tanzania, she did not call SunnyMoney (the company from which she had bought the light) but instead, after taking a closer look at the product herself, she realised

that if she *held* the cable that runs from the panel to the product in place at a certain angle or *balanced* it in that position, in a place where no one would touch it, it would charge. At this point (April 2016) Pamela's product was still in warranty but rather than seek outside assistance Pamela got her product working again, at home, herself. Pamela's repair was not a material alteration; she did not add or remove anything. It was a repair of practice: she altered the way she uses the product. Rather than inserting the charging cable with little thought, now she does so with care. Pamela was only able to effect this repair of practice through trial-and-error, it is only in some positions and not others that the product still charges. Other repairs of practice are sharing panels across products, charging products through the grid, connecting it to a car battery, only using it in daylight hours (in cases where the battery does not hold charge) and no longer using the product for lighting *and* phone charging but rather for one of the two. This section presents these different examples and shows that in the face of the types of breakdown described in Chapter 3 the most common repair conducted at home is not a material one but rather it is a repair of practice. Drawing on local resources, some as local as their own bodies, prior experience and through a process of trial-and-error shows that repairs of practice are a form of bricolage.

Rather than balance cables like Pamela did (or Martin, another survey respondent in Bungoma County on the border with Uganda), other users in the survey spoke of sharing panels across products. One user in Bungoma for instance told Lilian (one of the research assistants), that when one of her two SunKing Pro 2 panels stopped working, just over a year after having bought the products, she began using the remaining (functioning) panel to charge both Pro 2s. Similarly, when I was at Timothy's house in Brigedia, also in Bungoma County, he led me in to his bedroom and pulled out a box of panels from under his bed where they are kept safe from his children and thieves: "In the beginning people were stealing them" He told me. And so rather than place the panel on the roof as directed by SunnyMoney sales staff, Timothy would put the panel on a stool by the front door to his house, where it was less visible to passers-by. However, his children would then knock the panels off the stool and so, in Timothy's view, cause the breakdown. He prefers to leave the one remaining functional panel leaning against the wall of the house, but only when *he* is at home. They are kept in the bedroom as there they are "more safe" as his children cannot enter unless he gives them permission. The link in the solar assemblage that once connected each of these panels to one specific product was broken, instead Timothy now

used one panel to charge *any* product. Timothy drew on the resources he had at-hand, the box of panels under his bed. I encountered several other instances of panel-sharing during fieldwork. This sort of cross-fertilisation of different products is a habit also found in the repair clinic and company settings.

When faced with panel problems other users leave the solar element altogether and charge their solar product from the grid. The solar lantern becomes a grid lantern. In March 2016, when I walked around Bomet surveying all the retailers who sold solar in the town I often saw solar lights charging via grid extension cables on the table behind the shopkeeper (fig. 4.2). Some of these products lay in these phone, clothes and electrical shops because their panel was broken or had already been stolen. Others were there in order to evade theft; users bring their lights to town to charge during the day while they work, returning home with them in the evening. Grid-charging as a repair of practice then demonstrates the existence of pre-emptive responses to breakdown. The previous chapter (Chapter 3) showed that a breakdown is not necessary for a product to potentially become waste. Here we see that a breakdown is also not necessary for a repair to be enacted. The solar part of the solar product (i.e. the panel) is *not* always what the person in the varied user role values it for. Rather than be tied to the form of the product *and panel* the user values the product for the function it offers: light. How that light is produced is less important. Repairs of practice then show the preference for function over form.

Figure 4.2 A d.light S2 (to right) charges alongside phones and phone batteries in a mobile phone shop in Bomet (Author's image, March 2016)

At some point in 2015, the SunKing Pro 2 that Hellen, in Bungoma, had bought in 2014 stopped charging phones. Speaking to Juliet (the third of the three research assistants) in April 2016, Hellen said that she continued to use the product for lighting. Like Pamela, she altered her use of the product to accommodate the change. Hellen repaired herself with the fact that she would need to return to shops like that shown above (fig. 4.2) in order to charge her phone, no longer able to do so from her solar product. Like Timothy, she blamed her children and their curiosity for this diminished functionality. Hellen said that she would only consider contacting SunnyMoney if it got worse i.e. if the product also stopped lighting. This acceptance supports Rosner and Ames' idea of breakdown as a continuum (Rosner and Ames, 2014), not a linear or binary state. Responses to breakdown (repairs) like causes of it, are similarly varied. If Hellen's Pro 2 moves along the continuum and breaks down further then her repair of practice (accepting reduced functionality) will not be enough and she will go further (contact the manufacturer). Repair is not a final state but is often a temporary solution.

Users do not only adopt one repair. Nor do they apply the same fix to all products. When I visited Kenneth at home in Sango, Bungoma County, in May 2016, for instance, together with his son Brian, they explained to me how their two SunKing Pro 2 products are charged in two different ways. Sat in their living room Brian showed me how one of the Pro 2s, bought from the One Acre Fund, runs off of an old car battery which is stowed away behind a cabinet.[78] Brian's younger brother had set this up, attaching the product itself to a wooden ceiling beam over our head (fig. 4.3).

[78] One Acre Fund are a social enterprise who provide finance to farmers to help increase yields. The organisation has become a large distributor of off-grid solar products through its asset-based loans, particularly of the Greenlight Planet brand SunKing.

Figure 4.3 The SunKing Pro2 that Kenneth's other son attached to a wooden beam in their living room (Author's image, May 2016)

Meanwhile the other Pro 2 (bought from SunnyMoney) is stored on top of the cabinet (alongside a SunKing Eco and an array of kerosene lanterns). It is taken every 2 or 3 days to the family-owned shop a kilometre away to charge from the grid. The battery-charged one is an example of a more material intervention, the second type of home repair that is discussed in the next section. The point here however is that like the role of the user and the multiple people and places it represents, repairs are also varied.

Despite the fact that the original problem has not been repaired: for the grid-chargers, the panel has not been fixed or a replacement found, for Pamela, the loose connection has not been restored, the functionality of the products in these examples is returned and so the utility of the product is repaired. Rather than materially altering their product at the point of breakdown many users instead alter their practices to use the product in a certain way that enables some level of functionality even if a reduced one. Why accept a lower level of functionality? Why adjust yourself and not the product? Geographers Stephen Graham and Nigel Thrift (2007) offer one possible answer:

> When breakdowns and malfunctions occur, it is not necessarily the case that they can be easily fixed. The reason for the breakdown may be opaque…, the restoration may be too urgent for usual channels and procedures to be followed, the replacement parts may not be quite right but need to be made to fit (4: Graham and Thrift, 2007)

The repair of practice keeps some functionality. It is important to remember that the user does not have the quality standards or impact metrics in mind, their understanding of performance is not held to the same benchmarks. The imagined user, created by certified actors is effective in making users just that, users, not repairers. But in practice, urgency requires a solution is found. And so despite the lack of access to tools, spare parts or understanding of what causes the problem, the user is able to draw on other resources: themselves, the mains electricity grid, or other products to make their broken down products work to a degree, for a time. The function of the product is prioritised over its form. This and the inconsistencies it implies mean that a repair of practice is a form of bricolage.

If we understand repair as requiring tools and knowledge then these adjustments to practice may not appear as repair. However, as Spelman (2003) has shown, repair does not have to involve tools or materials but is more fundamentally about re-making relationships and that can be both returning things to a previous functioning or putting them towards a new purpose. Recognising the solar product not as a standalone object but as embedded in an assemblage of actors and ideas reveals repairs of practice that a focus on the physical product might miss. Highlighting these non-material responses to breakdown and taking a broader understanding of repair, shows how some users resist the role certified actors would have them play. The users themselves show an implicit recognition of the solar assemblage too. Hellen's ability to separate of functions: lighting and phone charging shows the product is made up of various elements rather than being a single whole. Meanwhile Kenneth's interaction with the grid and Timothy's use of other products and systems are evidence of the possibilities for re-assembling relationships within the assemblage.

Although they occur less often, more 'typical' forms of repair do also happen at home. it is to these more material repairs that the chapter now turns.

Material repair

> The light is designed to be used as it is built. The technical assembly of the Nova S200 lamp is locked – discouraging users from opening it, tinkering with it, mending it, or re-engineering it. Indeed, the lamp is built so that it can only be recharged with the small PV panel that it has been sold with; a design that is aimed specifically, the company has written, at 'preventing misuse and guaranteeing users do not connect the lamp to another power source'. (379: Cross, 2013)

The previous section showed how despite the company's best efforts, described here by Cross and encountered regularly in my own interviews, users *do* connect their lamps to other power sources, be they panels from other products (even other brands!), lead acid car batteries, and of course the grid. In one of the first critical engagements with the off-grid solar product in the social sciences Cross (2013) argues that the values of the market and market actors are inscribed into the very design of the product. The imagined category outlined at the beginning of this chapter: user as user, is made not just through the market devices that measure quality and impact or the marketing materials that convey those devices but are also built in to the product itself. The use of proprietary elements such as torx screws, unique battery sizes and untypical connectors are physical manifestations of the certified actors' attempts to discourage, as Cross writes, any opening, tinkering or mending. And it is again largely effective. Not only are material repairs rarely found at home, but those that do occur are mainly superficial. The main three material repairs that emerged in fieldwork are: re-taping cables or re-connecting wires, inserting a piece of wood, paper or card next to the switch to stop it from jamming, or using some thin rope or bent metal to hold a damaged outer casing together. Although now *on* the product rather than upon the user or the manner of use (as in repairs of practice, above), these material repairs remain external to it. This section takes these three most frequently observed and reported repairs in turn showing similar themes emerging: the use of resources 'at-hand', a minimal interest in form or aesthetic, and inconsistency in success or outcome.

In the survey, the most commonly reported material repair concerned the cable or wire (when internal to the product) that connects the solar panel to the circuitboard. Hilary, in Nandi County, told Getrude that one of the wires had become 'cut' in his d.light S2. This translation from the Swahili verb *kukata*, 'to cut', was used often in the repair clinic where I was an apprentice too (see Chapter 5). It was there that I learnt this did not

always mean ‘cut’ in English sense but would be better translated as disconnected, or become loose. Hilary reattached the ‘cut’ wire although admitted over the phone that the light was no longer as bright as it used to be. Another respondent in Trans-Nzoia County had a similar problem as had David in Nandi County, both also with a d.light S2. In response, his son who works as a repairman had fixed it. Again the user should not be interpreted as a singular or individual category, in this instance it includes the wider family. Beatrice in Migori also repaired the cable on her SunKing Mobile, after which the product was working well again. Not all repairs are successful however. Ezra, for instance, in Narok County failed to repair a wire within her d.light S20 and so proceeded to another response: taking it to the fundi - the repairman that is the focus of Chapter 6. While this inconsistency of success of repairs at home (and to varying standards) could be used to bolster the image of the user as ill-educated or incapable, it is actually characteristic of repair itself, that, unlike manufacture, is never the same. Harper describes this at length in his classic ethnography: *Working Knowledge: Skill and Community in a Small Shop* (Harper, 1987).

The switch was a popular issue in the survey (17 people complained of problems with it, more than the 10 complaints about the panel). Repairs of practice would involve holding It down for a long time (e.g. Daniel, Bomet County) or doing some “manual work” to get it to turn off (Jonathan, Bomet County). However, it was in during my apprenticeship in one independent repair clinic that I saw how some users materially respond to problems with the switch. When Christie, a schoolteacher, brought her d.light S2 in to the clinic in March 2016 she had already been using a small splinter of wood in her switch for some weeks (fig. 4.4 and fig. 4.5). The splinter stops the white switch from getting stuck under the red casing. Christie had materially intervened with her product in order to continue using it. What prompted her to bring it to the clinic was not the switch issue but a feeling that the light itself was dimming. Christie’s home repair shows both use of resources at-hand (bits of wood) and also variation in repair: the switch she was able to deal with herself, for the dimming light she sought the support of the professional repairman, the fundi.

Figure 4.4 Christie's d.light brought in to Malo Malo (Author's image, March 2016)

Figure 4.5 Second angle on Christie's d.light brought in to Malo Malo (Author's image, March 2016)

Chapter 3 described various causes of breakdown, of which impacts from falls off roofs, racks, stools and motorbikes were prominent. One result of such falls is that product casings can become cracked or damaged, this prompts some users to enact a material repair, others accept a repair of practice. Another visitor to the clinic where I was an apprentice, also with a d.light S2, was a man named Willy, who works at the County Government compound just across the road from the clinic. One day he came in with his product for repair. As was my practice I arranged to visit him at home and he kindly agreed. When I got there he showed me a second S2 that had a piece of metal bent round it (fig. 4.6). This, he told me, was because the screws in that product had become loose and so the metal held the product together. Similar to Christie, one repair he was able to do himself at home (addressing the loose screws), the second (the product was not charging) he could not and so took it to town. In addition to being another example of using resources 'at-hand': Willy told me that he had found the piece of metal outside his house, Willy's case shows that aesthetic appearance or form is less important than function.

F**igure 4.6** Willy's d.light S2s, one (to left) with metal wrapped round it (Author's image, March 2016).

Despite then an imagined user to the contrary there are some successful attempts at repair. This has also been found in other studies. In their study of a solar home system project in Zambia, for instance, Gustavsson and Ellegård write that

> A number of clients were reported to have connected inverters to the battery and by-passed the charge/discharge controller. This indicates that some clients know how parts of the system works, and how to obtain additional benefits. (1065: Gustavsson and Ellegård, 2004)

But in general, as George, from Tropikal Brands, the main distributor of Philips solar products in Kenya, told me, especially for the bigger systems (what he defined as being anything over 20 watts) you find that "there are very few who try to repair themselves". This matches with the survey where when asked about their practices with other household electronics (TV, radio and mobile phone) the bigger the product the more likely respondents were to have either already taken an appliance for repair or the more likely they said they would be to do so in the future. Users rarely spoke of taking small objects such as torches for repair.

Pragmatic repair

I did not see any children studying by solar light as shown in the image at the opening of this chapter, nor did I visit the exact users on the leaflet that Julius showed me. However, in visiting several other homes, where these products are designed to be used and indeed where the majority of their use occurs, like Christie (the schoolteacher)'s or Willy (the county government employee)'s, I saw and was shown a range of uses that reach beyond the user role that the certified actor, through its market devices, seeks to portray. None of the homes I visited for instance had the thatched roofs sometimes seen in marketing materials and Powerpoint presentations at international conferences. The portrayal of thatched huts is telling of the narrative certified actors want to tell their Western audiences (individual supporters and institutional investors) about poor, rural Africans. Yet the roofing material of houses has less impact on product performance than another aspect of the rural Kenyan home that was never mentioned in interviews, commented on in conferences or seen in marketing materials: the darkness inside. Overhanging roofs and small windows for protection from the heat and rain made a lot of homes I visited very dark inside, even in the middle of the day. Using lights in the daytime is another contributing factor to the over-use category discussed in the previous chapter but was never mentioned

by company representatives in interviews. The point, as set out at the beginning of this chapter, is that use is more varied than that imagined by certified actors. It is more varied in who, in where, and also when.

It is not just our understanding of use and user that needs to be widened but also of what it is that constitutes repair. If we take repair to be that conducted with tools and enacted on materials then we cannot see much, (see Spelman, 2003). In redefining repair to include non-material alterations we see a direct interaction between user and product involving hands and eyes as tools and knowledge acquired through experience with other household products. This iterative learning and embodied process of repair is similar to that observed in the repair clinic, and discussed in Chapter 5. But the part resolutions and temporary solutions that such an approach allows would be unacceptable in the company setting where quality standards and impact metrics still reign (see Chapter 6).

In entering those darkened homes (thatched or otherwise), and interrogating the certified image of the market, this chapter has shown that *t*he certified image is effective regarding repair, in all its forms. Users do little repair, and where they do it is modest (of their routine) or superficial (of the product). Most repairs at home are repairs of practice: they accommodate a new way of living with the product. Where material repairs are attempted they remain largely external (on the cable, switch, or casing). The chapter featured more examples of repairs of practice because it is more common. A broken product that was usable was not a concern to users who could work around peripheral or external problems. This lack of repair could support the company image of the user as lacking in knowledge that I was told about in interviews. The low success-rate of home repairs could be evidence of the user's forceful nature or their impatience as characterised by company representatives. Or, one could conclude that the imagined user, the stereotype, is effective. The ascription of the user's role as not including repair, by and large works.

Users do not do much material repair because they do not have access to the inside of the product, the necessary spare parts or knowledge. Business design through warranties, product design through difficult to reach screws, as well as marketing, and the historical development of the technology, keep users out of the products. Their role in the assemblage is to use, not fix. Gregson found similar exclusion in her investigation of household consumption in north-east England:

> the majority of us have very little idea of what is inside these appliances, or of how they do what they do. Most of us are not like Barry [a respondent who converts lofts, installs kitchens, rewires houses, does plumbing and rebuilds washing machines]. Instead, we are framed, through instruction manuals, as operatives of these things, not as their engineers. Our role is to push the buttons in the right sequence, to call the service engineer if appropriate, and definitely not to open up the inner workings of the machine inside, let alone to do what Barry does, experiment with and cannibalise the things inside to make hybrids. (140: Gregson, 2011)

We could add marketing materials and sales pitches to Gregson's instruction manual. The limited nature and range of repair happening at home is not just because users are not like Barry (although some are, particularly sons and boys it seems) but they are not *allowed* to be like Barry. This denial was recognised in a couple of interviews. Willis at KIRDI showed sympathy with users' struggles that telling me that:

> things break down, something very small, even the battery for example it's, it's worn down after two years or so, and these people don't know where to get another battery to replace it.

And then Simon, the founder of EcoSmart, told me that although it was quite easy to change the battery in EcoSmart products "the problem is where do they get the battery in the rural areas?"

Some however are less sympathetic to the user's plight. At times the users' attempts to

work around company business and product design are laughed at – in an interview one manager enjoyed the prospect of user's failing to fix products themselves.

The users I spoke to and those I visited were not however deliberately tampering with products or consciously acting against instruction. Nor do many of the repair motivations discussed in the literature (see Interlude) appear to apply to the case of solar repairs at home. Users implement repairs of practice (a change in *how* they use the product) or material repairs (a change *upon* the product) for pragmatic reasons. They do what they can because, as Graham and Thrift suggest, the restoration is too urgent to wait for other avenues (4; Graham and Thrift, 2007). Their actions are motivated by a need for the continued functioning of the household, to recapture the benefits they had been sold. The work of individuals like Kyle Wiens (founder and CEO of iFixit) is a prime example of where repair is supported by and pursued in the name of, an ideology: to divert electronic waste from landfill and to reclaim the right to repair from corporate manufacturers. But

Wiens has himself written of his original interest in repair not being political but instead practical (40: McLellan, 2013).

Users might be doing this for many reasons. Although not necessarily describing it as pragmatism, Africanist scholars of infrastructure have written of similar responsiveness in everyday African society. Clapperton Chakanetsa Mavhunga for example claims that

> African history is replete with examples of people adjusting their traditions to craft self-help solutions to everyday challenges and to selectively tap into resources from outside (7: Mavhunga, 2014)

While Trovalla and Trovalla identify a similar "state of constant improvisation and experimentation" (333: Trovalla and Trovalla, 2015) in the face of the uncertainty of daily living in Nigeria. Another reason could be based on users' experience with other electronics. A solar product is not the user's first electronic device nor when it breaks down is it their first experience of electronic breakdown. This connection to other electronic devices (or electrical appliances) is another thing that the imagined user category forgets.

Self-help and self-fixes do not always come off however. In the survey, Hilary told Getrude that he had previously tried (and failed) to fix an issue with a mobile phone. At this point users can again turn to their experience with other electronics and seek outside help. Despite the certified actors' best product and business designs, many users will respond in this way. The drawing on previous experience, even if not to actually perform a repair, could be evidence of bricolage thinking if not bricolage practice. The term helping capture both approaches to repair as well as repair actions. The repairs described in this chapter often then precede repairs in electrical and electronic repair clinics or at the company premises, as chapters 5 and 6 will explore. But as those chapters show, even when the product has moved beyond the home physically, how the home and its inhabitant are imagined continues to shape how repairs are conducted, if at all. When material repairs do occur before a product arrives in the clinic (Chapter 5) or the company (Chapter 6) the imagined users and homes are also carried to these other locations. The visible signs and traces left in or on the material product from a material repair then can fuse with imagined ideas of user, use and cause of breakdown to influence the repair process in these other settings as well.

Repair, however is just one response to breakdown. Some users do not respond. They might also simply accept the breakdown. Several people in the survey for instance spoke of how their product had just stopped working. But rather than identify a particular

cause or moment, or complain about the product's functionality they seemed to interpret the finishing of a product as somehow inevitable or natural. This could be one driver then in not pursuing other actions, at least not immediately. Other users still rather than repair (or after having repaired) broken down products put them to new uses or move them to new places to live new lives. It is these new lives that are examined next.

Rural, domestic e-waste

To do so, and to further understand the gap, the chapter turns to a different body of literature that which discusses household consumption, drawing particularly on Gregson's work in the UK (Bulkeley and Gregson, 2009). This is because much of the work on e-waste in the Global South to date has concentrated on urban centres and has done so through lenses of informality and governance (see Millington and Lawhon, 2019 for a well-structured literature review). Indeed, in their outline of how waste is studied differently in the Global South, geographers Nate Millington and Mary Lawhon suggest that: "waste studies can usefully benefit from thinking across north-south binaries" (1045: Millington and Lawhon, 2019). Such a move is also in line with the postcolonial agenda that challenges empirical and intellectual dichotomies between the North and South (see Comaroff and Comaroff, 2012). Rather than the gap being a "point of departure in the trajectory of the discarded from that of its Western counterpart" (47: Bhattacharya, 2018) then the gap is found to be a point of convergence. Bhattacharya's justification of that is the divergence in regulatory norms, which is often true again as Millington and Lawhon's review makes clear. However, in responding to their call for more research in to "everyday waste practices" particularly in "their more mundane forms" (1045, 1051: Millington and Lawhon, 2019) the rest of the chapter shows the similarities in waste management between North and South, at least waste management within the home.

While the volumes of products disposed of at home are smaller, in the rural, domestic setting the effects of disposal could well be more immediate. Much e-waste research has been environmentally motivated, concerned with the effects of 'improper disposal' on human and environmental health. Yet, if, as the next sections discuss, users dispose of their solar products at home they could be contaminating water or land supplies sooner than at urban sites of consolidated waste which have long been under the scrutiny of activist and academic attention (see Greenpeace, 2005; SVTC, 2014).

Waiting in 'the store'

Larkin, like Trovalla and Trovalla (2015), identifies breakdown and repair as part of everyday living in Nigeria. He writes that

> In Nigeria, all technologies are variously subject to the constant cycle of breakdown and repair; the promise of technological prosthesis is thwarted by the common experience of technological collapse. Each repair enforces another waiting period, an often frustrating experience of duration brought about by the technology of speed itself. (235: Larkin, 2008)

The idea of waiting recurred again and again in fieldwork in Kenya too. In addition to "waiting for e-mail messages to open, machines to be repaired, or electricity to be restored" (236: Larkin, 2008) users of solar products, and the solar products themselves, wait before disposal. With some awareness of risks to the environment through local disposal (in the ground, bush, toilet or fire), user's disposal at home, as with repair, is limited. Instead of disposal users hold on to their broken down products as mementoes or symbols of their social status, as teaching aids or as toys. Some hope the products will begin working again at some point, or that the company that sold the products to them will return with advice and others still plan to one day take them for repair. Unlike the pragmatism behind repair these other responses to breakdown are driven by uncertainty. Users are not sure what the 'right' thing to do is, nor are they sure what the future might bring and so, in the meantime products sit in the gap waiting. This section discusses what is the most common response to breakdown at home: holding on.

Timothy Lusamamba bought three products (a SunKing Eco and two SunKing Pro 2s) from SunnyMoney in 2014 when the company came to the school where he was headteacher in the east of Bungoma County. During a conversation with one of my research assistants in 2015 Timothy told us that he had previously thrown away an old solar product (not bought from SunnyMoney) when it was no longer working. Yet when asked about what he will do in future he said he will seek repair, either from the company, or from an independent repair person. The gap between Timothy's actions (throwing away the solar product) and his intentions (pursue a repair) appeared repeatedly in conversations with users at home about how they deal with broken down solar products.

When I began the survey through which I came into contact with Timothy, I expected what William Rathje and Cullen Murphy call the "materials-flows assumptions" to hold, as they had done with their 'Garbage Project' (189: Rathje and Murphy, 2001). The

"materials-flows assumptions" states that whatever is sold then flows in to waste streams after its expected lifespan is over, once its use to the consumer is complete: that is to say that if X million solar products had been sold in Kenya in 2011, with an expected lifespan of 5 years, then there should be an estimated X million such products in the waste streams five years later in 2016. Yet, in a week recording all 'major appliances' brought to Tucson's Los Reales landfill Garbage Project researchers came across very few. It turned out large appliances, and furniture, would be scavenged from the streets of Tucson before the garbage collectors arrived to take them to Los Reales.

Michael Schiffer, an "ally" of the Garbage Project led a subsequent study to look in to this discrepancy more closely (191: Rathje and Murphy, 2001). Schiffer's 'Reuse Project' went, like this thesis, to the place before the dump, the household, to ask residents whether they had recently disposed of any major appliance or piece of furniture. The results of the survey are proportionally similar to my own. 34% had been sold or given to strangers or stores, 30% were still around the house somewhere, 29% had been sold, given, or loaned to relatives and friends and just 6.2% had been thrown away (189: Rathje and Murphy, 2001). In the survey of solar users the percentages were different but the relative trend the same: 65% had kept a broken solar product around the house, 11% had returned or replaced them with the company, 4% had given them away to family and neighbours and 4% had thrown them away. In the USA and in Kenya more happens to used electronics it seems than throwing them away.

Users spoke of products being kept in the house, or that it was in the 'store', the 'cupboard', or less specifically that it was just 'there'. This is the gap. And unless another action is taken many said these products had already or would eventually become lost. The reason that the materials-flows assumption does not hold is that products move in to this gap.

But why? One answer emerged at the end of the survey when users were asked: "Is there anything else you would like to share?". While lots of respondents used the opportunity to complement SunnyMoney on the products or asked where and how they could buy more or bigger products, some users asked for advice on how best to dispose of their broken product:

'Can I ask if it is dangerous if it stays in the house?'
'We should be told how to discard the lights if they get spoilt.'
'Are they harmful if one decides to burn them?'

These, and other questions, are reminiscent of Gregson and colleagues' study of consumption in the midlands and north-east of England where their respondents expressed uncertainty and anxiety:

> over whether such matter can even, should even, be placed in the bin, presumably because of vaguely felt but barely understood concerns over environmental effects. (687: Gregson et al., 2007)

The uncertainty that drives users to hold on to products in the home is also a motivating factor for other actions though, as is demonstrated in the next section. Potentially confusing this shared motivation driving action and inaction makes sense when realising that users do several different things. Users' responses to breakdown are not one-off and finite decisions. This again matches Gregson's work where:

> Ridding events, then, were disclosed not as discrete events marking key moments in the social lives of things, their passage from one value regime to another. Rather, they occurred as part of a seamless flow of appropriation and divestment, storing, keeping and holding, involving an array of things in the domestic sphere. (20: Gregson, 2011)

Although reaching the discrete percentages offered above required coding the responses of the survey and so separating out events, responses were often more complicated than that. Some users spoke of doing several things while others had forgotten or did not know where the product was, this inability to recall the action suggesting that ridding was not a key moment, but part of the daily rhythm of living with things in the home.

The majority of users do not repair at home (as discussed above) and many do not move their products on in to independent (Chapter 5) or authorised repair processes (Chapter 6). For most users the first response to breakdown is to wait and hold products in the gap. Users wait because they have been told at the point of sale not to intervene or they do not have the knowledge or the parts to do anything else. While some products fall deep in to this gap to be lost, other things can happen. The next section describes these other actions.

Other actions

These other actions include: storing, giving, selling, taking, dismantling, burning, burying and dumping (which can also involve siphoning on the way to the dump or scavenging from the dump later). This section discusses some of these other forms of disposal.

A different survey respondent Michael Tanui, in Mulot, 24km down the road from Bomet told Getrude that he did not know what would happen should any of the three d.light S2s he had bought fail in the future but suggested that his children will probably take it, play with it and eventually it will get lost. Michael was not the only respondent who said that either they will give a broken product to their children to play with or that their children will take and play with it of their own accord – a sort of siphoning off. Fearing such was the reason Steve in Bungoma County was keeping his (already broken) SunKing Eco in a drawer he told me otherwise "my boys can take it, it can be stolen".

The use of broken products as playthings is ironic as one challenge for the certified actors when dealing with national governments in Africa is a conception of off-grid solar products as toys. This is presumably partly due to their size (typically small), colour (often bright) and their capacity (quite low). During a mid-morning interview, Country Officer for Lighting Kenya, Nana Asamoah-Manu said,

> In fact I remember at the Ministry level, one of the PSs [Principal Secretaries] was so sceptical, not because of us, but because he felt 'why should the World Bank and IFC waste their time on these things that are basically toys and they don't really work?'. I mean based on his experience in the market they should think of bigger things like grid.

Cross has encountered similar attitudes when conducting research in India (Cross, 2017). There is a second irony in the sale of these solar products to aid study yet children benefit from them when broken too. Some children are given the broken solar product to take apart to figure out and learn how they work.

Children benefit in other ways from broken down solar products too. Teacher Samuel, for instance, whom I visited at home in May 2016 told me he would hold on to the wires from his broken products for "practicals" in the classroom. This was also seen at Karamugi school, one of the original four in which Mark Hankins and Harry Burris installed systems in the 1980s (see Chapter 1). When I visited in November 2016 I was told that some of the old panels of the now-defunct system are used for demonstrations in Physics lessons. This re-invention of solar equipment shows a different kind of educational value than that marketed by the certified actors (see Chapter 2). While the products might aid evening, or early morning study, as the marketing materials espouse, solar products are also used as learning aids in and of themselves.

Schools also feature when users discuss local scrap merchants – another destination for solar waste. When I visited Steve at home in Bungoma County I asked him

whether there were any scrap dealers or collectors in the area. He told me there were very many: “they use our schools” he said. Scrap collectors periodically visit schools to buy scrap metal (mainly old cooking pots) or swap it with students for stationery (biros and books). Steve explained that they would typically come 1 to 3 times per term. “The students will steal from parents, teachers say: ‘No, this one is good. Take it back.”. This sentiment was echoed by another survey respondent, Bernard, in Elgeyo Marakwet County, who explained that such school visits had previously been the case in his area too but the practice had since been banned because children would take objects from home and deliberately spoil them so that they could sell or swap with the scrap dealers. A third respondent said that the collectors deliberately target children as they know they are more likely to give things up than adults. Steve told me that “sometimes they even come as far as houses”. Regardless of where the collection was done, at schools or from homes, more respondents were scathing of the little amount of money they would receive and whether or not these scrap collectors would even be interested in solar products (with minimal metal content, often just a stand or panel frame). “What can 5 shillings buy?” Dorcus asked me, when I visited her at home: “[It] can't even buy a ¼ of a cup of sugar” she said.

With little incentive then to sell their broken down solar product users move to other actions still, like burning. And again here children were central to the process. Amos for instance in Bomet County told Juliet (in 2015) that he will burn his d.light S2 at some point fearing that if his children play with it, it might be dangerous. Although when this option was put to the whole survey sample a year later in 2016 some did speak of the dangers of burning: that it would bring disease, pollute the air and could be deadly for cows.

Instead of burning some users would use the same reasons: protecting children or protecting the environment as justification for putting their broken solar products down the toilet. When discussion over soda in Samuel’s front-room (of two) turned to disposal of solar lanterns he said that “If they [solar lights] are broken they can injure them [children]” so he would put the glass (referring to the solar module) in the pit latrine (see fig. 4.7).

Figure 4.7 The latrine where Samuel plans to put his solar panel when it stops working (Author's image, May 2016)

Views like Samuel's and Amos' are reminiscent of Robert Hertz's description of funeral rites in Borneo:

> Death, in fact, by striking the individual, has given him a new character, his body, which (except in certain abnormal cases) was in the realm of the ordinary, suddenly leaves it; it can no longer be touched without danger, it is an object of horror and dread. (200: Hertz, 1961)

The breakdown, like death for the Dayak people, can transform users' perceptions of a solar product from something good enough to invest money in (often for reasons of health or education) to something threatening. Opinion on latrine disposal was also split however with some suggesting that nothing would happen and that this was a safe method of disposal but the majority warning of explosions, chemical reactions and radiation.

Although Dorcus was one of those who planned to put her product, a SunKing Pro 2, in the latrine she did worry that the toilet would fill up as a result. And so she would bury the battery she said (see fig. 4.8).

Figure 4.8 Dorcus gestures to where she normally buries waste, at the foot of a banana plant at the end of her plot of land (Author's image, May 2016)

Others cited their uncertainty as a reason to bury their solar products. Because they do not know what is in it or what might be harmful then they will bury it. Although once again opinions were mixed with some expressing concern for soil pollution, many unsure of what would happen and a few believing that as long as it was buried deep enough then there could be no further risk.

The final action that emerged from the survey was to throw away the broken down product. Few gave reasons for this decision it was 'just' or 'simply' the case when there was no other option left. Nor did all users specify how or where they would throw the products away. If not just in a nearby bush on their land we can assume these products would also end up being burnt, buried or put down the toilet as these are common and typical methods of disposal for household waste in rural Kenya (Kipkoech, 2014).

First and second burials

The most frequently reported response to breakdown is to hold on to the products at home. Some users do this with the intention of performing another action at a later time. For others the holding is the end, at least for the moment they have no plan to do anything else with it. The holding is characterised by putting the product, or part of it, under a bed, in a drawer or on top of a cupboard. These moves mark what Hetherington, drawing on the work of Robert Hertz, calls the first burial (Hetherington, 2004). Other forms of the first burial are to keep the product as a *kumbusho* (memory) to hang on the wall. When I visited Timothy at home he told me he keeps his non-functioning solar panels for "remembrance".

After the first burial comes the gap where products wait.

At some unspecified point after that come the other actions discussed above that constitute either a new life: using products as toys or educational aids and selling them for scrap, *or* the second burial: burning them, putting them down the toilet or burying them. The choice of when to move a product from first to second burial or move it elsewhere from the gap is an uncertain one. In the follow-up survey when asking users what they thought might happen should a solar product be burnt, buried, thrown down the toilet or left in the house, a large number of respondents simply told us "I don't know".

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Through the survey or after a visit, perhaps prompted by our discussions and my visit users would call or text me asking for advice on what to do, or who to contact in the event of a breakdown. They would often ask me what should be done, where they should go et cetera. In the framing of the imagined user this not-knowing is because they are not educated but the same ignorance could be framed as uncertainty: they are unsure what to do. For many users the survey was the first time they had heard from a solar representative in months, possibly even years, and so they would ask questions of us. Because he had not heard from SunnyMoney for a while when I visited him at home in May 2016 Samuel told me that: "I thought maybe the company had closed". The survey call reminded him to try again with SunnyMoney about the problem he had. This then is an example of when my research was an actual intervention in the processes this thesis describes. One must assume that others adopting the telephone survey method, such as Acumen, will be facing similar concerns from customers. This is certainly an ethical challenge to be considered when choosing one's methods. It was not however one I had

thought of pre-emptively. In response I told users to contact SunnyMoney directly and reminded them of the contact phone number if they did not have it: the research assistants and I had made the survey calls from our personal mobile phones.

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In the absence of guidance from solar providers and retailers a lot of user disposal practices, like their repairs, are informed by experiences with other electronic products. This serves as a further reminder to consider and examine these solar products in the context of household consumption rather than approaching them through the lens of e-waste. It is only by concentrating on the act of wasting rather than the stuff of waste that this variety of practices and the dual burial can be seen. As practices they would be hard to retrace when waste is already consolidated in urban dumps where the attention of e-waste research has focused. Consciously taking a different focus in looking at rural, domestic e-waste the range of actions described in this chapter has demonstrated that very few solar products are making, or look likely to make, their way *as waste* to the urban centres. Admittedly they may end up there by other means through the prism of independent or authorised repair processes which is where the next two chapters move.

Chapter Five

Repair and disposal at the clinic

An old profession

When I asked electronic and electrical repairmen how they first became involved, or got interested in repair they often referred to their childhood. I asked one repairman, called Hesbon, how he had learnt electronics:

> *Mimi, hii ni kipowa, nilizaliwa nazo tu*, [For me, this is a talent, I was just born with it] yeah. When I was Class One I started *ku*repair watches, I started with watches when I was in Standard One. Standard Two watches. Standard Three *nianze kutengenza redio*, so *ni kitu nilikuwa nayo* [I started to fix radios, so it's something I have always had], yes.

This locating of one's affinity to repair in experiences as a child is well-established in the repair studies literature. In the introduction to his 'teardown manual for modern living': *Things Come Apart*, artist Todd McLellan, for example, describes having taken apart his childhood toys (McLellan, 2013). Many of the artists Jackson and Kang (2014) worked with in New York describe similar childhoods spent disassembling G.I. Joe dolls, Video Home Systems (VHSs) and radios (453: Jackson and Kang, 2014).

It is not just within personal histories of repair that people point to the past however. Despite the modern flavour that contemporary objects of repair: mobile phones (Houston, 2013), cars (Dant, 2010) or photocopiers (Orr, 1996) might suggest, Steve Jackson describes repair as "ancient…even timeless" (226: Jackson, 2013). Archaeologist Ian Hodder takes a more precise starting point in 12,000 B.C.E when humans started to live in mudbrick houses. Hodder argues that every new human-made thing since that time has required further human-made things to fix the problems the new introduction creates (Hodder, 2014). Electronic and electrical appliances such as TVs, radios, and solar products requiring new furniture to house them, more media content to fill them or extended distribution channels to sell them are examples of such.

When I interviewed Willis, the Head of the Renewable Energy Division at the Kenya Industrial Research and Development Institute (KIRDI), he told me that the tradition of electronic repair is well-established in Kenya:

> it's quite old and mainly it, you find artisans, technicians, dealing with what is called repair work of systems and they repair up to component level. And so when you talk about skill actually, skill is there, skill exists. If you walk around the streets of Nairobi you will find shops all over, breaking TVs apart, putting in new components, and getting the TV working and so that's happening.

It is significant that Willis uses the word 'skill'. In Kenya, those who earn their living through repair are known as *mafundi*, or *fundi* (singular). The word *ufundi* means 'skill'. It is one of a family of words concerned with teaching (*kufundisha*) and learning (*kufunza*). The fundi is a skilled individual who works with their hands to make something function. This could be a new thing: like a flashing LED sign board for a shop, or an old thing: like a CRT television for a café. They might work with wood (fundi *wa mbao*) or they might work with metal (fundi *wa chuma*). The profession, that is ubiquitous across communities in Kenya, is united then not by the material it works with, nor what it produces, nor still the tools used. Instead it is the manual nature of their work, and perhaps most crucially how that skill has been acquired that identifies an individual as a fundi. Although there are numerous types of fundi such as: *wa gari* (vehicles), *wa stima* (electricity), *wa baisikeli* (bicycles) and *wa piki piki* (motorbikes), the type of fundi that is the focus here is the fundi *wa TV na redio* (who work with electronic devices and electrical appliances more generally).

Other terms are sometimes used in the literature and in interviews. In Kenneth King's foundational studies of the informal sector in Kenya for instance he refers to the mafundi as 'artisans' (King, 1975; 1977; 1996). And during interviews interviewees spoke of: "technicians", the "technical guy" or a "sort of repair guy". Here however I stick with the word 'fundi', the term that mafundi use to describe themselves, and the term that is used by their customers. This also avoids confusion with 'technician' which is used in Chapter 6 to describe technically-oriented employees of solar companies. Another term that is sometimes heard in relation to mafundi is *jua kali* (hot sun) which is a broader category for the informal sector in Kenya. Originally referring, in the late 1970s, to those working in the open air, without premises, the term has since come to refer to anyone working within the informal sector. The mafundi featured in this chapter all identify as *jua kali* on the basis of their self-employment and daily income.

Answering Jackson's calls for researchers to:

> expand our cast of characters, including but certainly not limited to the breakers, fixers, and maintainers (234: Jackson, 2013)

This chapter introduces the fundi to repair studies. The fundi is also introduced as another character in the solar assemblage. The chapter argues that the fundi's work, like the origins of their expertise in childhood, is similar to the work of the menders, fixers, mechanics, tinkerers, hackers and repairers already present in the literature. Still working with the concept of bricolage allows us to see the similarities across contexts. They are all, like the user at home (see previous chapter) bricoleurs. Although doing a lot more repairs, a lot more of which are *material* repairs, than observed or reported at home, the fundi proceeds in much the same way as the user, through trial and error. The fundi's work consists of drawing on previous experience, using parts from other objects and prioritising functionality over consistency or aesthetics. And also like the user at home the fundi's repair is limited by factors beyond and outwith their control such as business design, product design or manufacture. Once again the devices define limits and keep the fundi out of the process like they do the user. However, what makes the fundi distinct from the user and those fixers already present in repair studies literature is the difference in their motivations. Rather than repairing for pragmatic reasons (as users do), for joy, political protest or environmental beliefs (as the literature suggests others do), the mafundi in Kenya work to fix objects so as to provide for their families. Theirs is an economic motivation to make money.

The data in this chapter comes from observations in independent repair clinics in Bomet. It draws mainly from a three-month apprenticeship in one particular repair clinic. The other observations of repairmen were limited to one day in each different clinic. Having begun with the three-month apprenticeship however gave me some credence and some basic skills to access and then be taken seriously in these other settings despite the short stay. Observations with scrap collectors and waste workers are also drawn on as well as home visits of customers of the clinic where I was an apprentice.

The chapter begins by introducing the two mafundi I worked most closely with: Wilson and Hesbon. Their ethnic identity as Luo and practical training-by-apprenticeship shapes the day-to-day work they do in their clinic and the social networks they can draw on when working away from their families (as is common). Although conducting what has been described as feminine work (repair as a form of care) being away from one's wife

contributes to the masculine nature of the professional repair environment and reinforces the need to earn money to support one's family. The second section turns to the daily work of the clinic: the space, tools and reputation of fundi repair. The third section attends to 16 solar repairs worked on during a three-month apprenticeship in one particular clinic. The unimportance of solar products within the broader suite of electronics in the clinic both in terms of frequency and in terms of economic return re-iterate the financial motivations at the heart of the fundi's work. The chapter argues that while repair might be innate to human existence, it is the *way* repair is done that we share not *why* it is done. The later parts of the chapter turn to a particular clear out of the clinic that I assisted in. Following a self-employed scrap metal collector who periodically passed the clinic looking for metal to take away and on to the waste management process operated by the Bomet County Government which takes care of that which is left by the scrap collector and not taken opportunistic passers-by. The chapter finishes by stressing that, like at home, most broken down products are held on to in the clinic. Mafundi do not know which part of which old appliance might provide them with the spare part to fix a future product when it is brought in and so in the face of that uncertainty, they will hold on to such bits and pieces, or sediments, just in case.

Luo-men and learning

When I first arrived in Bomet in January 2016 I set about finding a fundi who might accommodate me as a participant-observer, or apprentice. I wandered the streets and asked various passers-by and local shopkeepers where I might find a fundi who can fix electronics. I was directed and sometimes re-directed to various places around town. I was taken to one in a hut out the back of the bus station, where I saw a soldering iron being heated in a burning kerosene cooking stove. And I was pointed to another down an alleyway that led in to a courtyard with a hairdresser's, a clothes shop and a fundi. One however stood out. Not only because it was on the main road, signposted and had a crowd of people outside it but because, craning to see inside, I saw a box on its back shelf from my former employer: BBOXX. BBOXX are a SHS manufacturer and distributor. I was surprised to see the box of a BBOXX TV here for two reasons: one, because at the time, and until the time of writing (July 2018) BBOXX were only selling in the Nyanza region of Kenya, 130km further west, and two, because at the time I was not sure whether off-grid solar products were even moving into and through the local repair economy that the mafundi represent.

In later visits to the other 6 repair clinics in the town I would discover that they too had solar products on their shelves, walls, floors and benches, but they had not jumped out at me as the BBOXX one had on that first visit.[79]

I asked the mafundi at this clinic*:* two men named Wilson and Hesbon, if I could spend some time with them over the coming weeks, watching (and to an extent learning) their work. They agreed and so I spent the following three months at the *Malo Malo TV na redio clinic* (fig. 5.1) observing and participating in the work of a fundi.

Figure 5.1 *Malo Malo* from the bank up to the main road (Author's image, March 2016)

This section of the chapter introduces three broader aspects of the fundi category that shape that work: ethnicity, education and gender. Mafundi in Kenya are historically from the Luo ethnic group. This shared identity and the fact they often work away from home were explained to me in terms of economic advantage. Meanwhile the centrality of the apprenticeship (often through a family connection) as the path to becoming a fundi

[79] Instead it was in the moments waiting around that is a part of the daily routine in these clinics that my eyes would chance upon another product tucked away in the roof, stuffed at the back of a shelf or sediments of one scattered on the clinic floor.

means repairs in the clinic emerge from acquired, practical experience. Thirdly, the clinic as a masculine environment feeds in to understandings still dominant in contemporary rural Kenya; that a man should financially provide for his wife and family.

Both originally from Nyanza (the region in the west of Kenya where BBOXX operate), Wilson and Hesbon are Luo, the fourth largest ethnic group in the country - a group I would learn are disproportionately represented in the fundi category. During the course of my fieldwork I often heard that the Luo were famed for being fundis: taxi drivers in Nairobi told me that the Luo were 'good with their hands' and in Bomet locals (from the Kipsigis ethnic group) said that the Luo are 'the best fundis'. Not just in electronics but across other fundi 'disciplines' such as carpentry, mechanics and metalwork. When I asked Wilson if this was just coincidence he told me:

> you know this country we have many tribes. But every, every tribes have got their knowledge, their experience eh? … So you know in Luoland [Nyanza], a long, long time ago they have to learn something, they have to, all of them are Luo they start to learn something one by one. They, a long time ago, if you take something to a Luo person, a Luo man or somebody from Luoland even this, this wine *[picking up the glass bottle of my soft drink]*, he want to know which is this thing? What is it? Eh? Ah how do, how do they manage to build this bottle like this? And what is inside it?

Wilson continued, telling me that if you give *some* people something they "don't care, he can use it and put it there and he can, and he go home." But a Luo man will want to know how that thing works in order to either make, fix, or improve one for himself.

Mafundi are not exclusively Luo however. Indeed, only half of the 12 mafundi who operate in Bomet are Luo.[80] Crucially though, of the other 6, only 3 are local to Bomet. The others came from Kericho and Kisii; larger towns to the north and west. Like Wilson and Hesbon, they too were working away from home. When Wilson and I sat down for an interview in August 2017 he told me:

> if you are near your friends and neighbours or family you have to help them without payment. So what you can do, that's why you see a lot of people go far, far, away from their villages so if you can help somebody to do something he have to pay you something also.

Unlike the 'Barefoot Engineers' that Stewart Allen studied in central Rajasthan, India (Allen, 2011), who are sent *back* to their home villages after their training with the intention that

[80] I spent a day shadowing each of these other mafundi in Bomet's 6 other clinics during a return visit to the town in August and September 2017.

they remain there, mafundi generally (and deliberately) work *away* from home. Working away from home is a financially motivated decision; you have to do it in order to get paid. This does not mean however that mafundi work alone or are isolated. Rather the opposite is true. Mafundi form new networks in the place where they operate. When I asked Hesbon in an interview why he did not have his own clinic, rather than share with Wilson, he told me that you cannot do it alone. These networks are formed on ethnic lines. Every lunchtime during my three months at Malo Malo, for instance, we would eat with Luo mafundi (*wa nguo* (clothes) and *wa piki piki* (motorbikes and generators)) who worked nearby and often in cafés where they serve *omena* (silver cyprinid) – a type of fish that is native to the Nyanza region that Wilson, and others, refer to as 'Luoland'. Other Luo mafundi (*wa TV na redio*) would also drop by at various points during the working day to consult Wilson and Hesbon about a particular repair that was troubling them or, more often, to share tips on the day's football betting. This friendship group also involved several savings groups where each pays a small amount in to a joint account daily that a member can then draw on if they want to make an investment in their home, business or need to pay larger 'one-off' sums like school fees for their children.

The ethnic network is also important for training and opportunities. Hesbon, for instance, initially travelled from his home in Nyakach, Kisumu County (in Luoland) to Eldoret (out of Luoland), further up the Rift Valley from Bomet to be trained by an uncle of his. He later moved to Bomet to be near his brother who was practising as a mechanic (fundi *wa magari)* at the time. And it was because of the Luo connection that Hesbon and Wilson found each other in Bomet (ca. 2008[81]). Wilson had come to Bomet a few years earlier in 2005, again on the recommendation of "a brother". Having done his initial training under the tutelage of a friend at a transit town called Chemelil, Kisumu County (in Luoland).

Although many mafundi would refer to their childhood as being the origin of their repairing skills, many complement this early curiosity, ethnic belief and apprenticeship with some formal training. The combination of learning-by-doing with more formal study is not dissimilar to the paths taken by Hankins, Keane and Blyth in Chapter 1 who each sought academic degrees to go with their on-the-ground experiences. When Wilson's father died, the family finances were affected and so Wilson's mother paid for him to study electronics at a polytechnic which would be cheaper than the fees, uniform and books needed for the

[81] I say circa 2008 because Wilson estimated they had met in 2007 while Hesbon told me it was in 2010.

final year of secondary school. I was initially surprised that a fundi would have gone to college. Having been told by Wilson, Hesbon and others that they were *jua kali* and so part of the informal sector I assumed that those within it would not have received formal training. Willis at KIRDI explained it to me in terms of available jobs. They go "through some formal training, they got some certificated [up to diploma level]" he said, but because they cannot get formal employment "they open up their small enterprise", their clinic. An alternative appraisal of the need for certificates and diplomas was given to me by Mike, a *fundi wa piki piki* (motorbikes and generators) who worked on the ground outside Malo Malo and kept his toolbox in the clinic overnight and his jumper there during the day. Mike told me that formal certification helps mafundi secure contract work from institutions like the County Government for instance, who need such documents in order to award tenders.

One thing that is constant across the fundi category is gender; they are all men. Although as Jackson (2013), and Spelman (2003) have argued repair is feminine in many ways (as care in response to vulnerability; Callén and Criado 2016) and the previous chapter demonstrated the greater care shown by women and girls towards solar products at home, the clinic, like Willy's workshop in northern New York (Harper, 1987) and Reg's garage in the UK (Dant, 2010), is a male-only space. In a survey users also spoke of the *fundi* as men and where acknowledged in interviews the repair person was a he too. Wilson and Hesbon's friendship group was all men as well; many of whom were also working away from their wives.

The bricolage business

Wilson told me proudly in our interview: "Most of them, most of the people in this country love, love us because of our works." The status of the repairworker in society is also discussed by repair scholars. Houston and colleagues (2016) write of the mobile phone repairers in Dhaka, Bangladesh as holding "backstage roles that come with low pay and low status" (1411: Houston et al., 2016) while Dant suggests that the "manual and dirty character" of repair work has contributed to it being devalued over the twentieth century (8: Dant, 2010). Yet neither Malo Malo nor the other 6 clinics I observed appeared lowly or dirty. Although there was dust, insects, fumes, glue, and kerosene to contend with at Malo Malo, every day began by sweeping out the floor of the clinic. Similarly, the desk and workbench would be sorted at least once during the day as well. Cleaning the object was one of the first and final steps involved in any repair. Indeed, on occasion cleaning the

product (or parts of it) *was* the repair (such as wiping with kerosene to remove residues on the circuit board that reduce conductivity). Wilson and Hesbon also regularly wiped their hands together or off a rag to clean them.

Despite Wilson's claim of adoration, I did encounter negative views of the fundi during fieldwork. Interviewees in Nairobi spoke derogatorily of the ability of mafundi to fix solar products. Gijs, at Barefoot Power, for instance described to me how

> the local chief in the village, right, the guy who knows how to put two wires together he, he then acts as a sort of repair guy right? And he starts doing stuff.

Gijs' use of the word chief reveals a lack of understanding of rural living in contemporary Kenya. But more than this the skills he this "repair guy" has are belittled. This belittling peaks when Gijs explained how any attempt to re-wire the circuitboard of a Barefoot Power product will "just short-circuit it!" Breaking in to laughter he told me "they [the repair guys and users] don't know that but they will, they will try it, they try to repair, they fail"

Users spoke also suspiciously of mafundi. Telling the research assistants and I, in the survey, that mafundi would lose products, that they would not be able to fix solar things or that they, a neighbour, friend or family member had had an unsuccessful experience with a fundi in the past. Ironically past experience (i.e. getting a mobile phone or radio fixed) was also quoted as being how a respondent knew that a particular fundi could repair solar products as well, having seem them do so when at the clinic with another of their electronics.

At Malo Malo users would often come repeatedly to check up on the status of their repair, not knowing necessarily, as I did, that often no further action had been taken on it since they last checked. Most repairs happen as customers wait. If a customer did not wait, then others who did would move ahead of them in the queue of jobs to be done. While I could empathise with customers' frustrations at the time they had to wait for a repair to be done, often returning several times over several days or even weeks to remind Wilson and Hesbon, I did not observe any deliberately misleading or malicious work at the clinic. I mostly observed conscientious efforts to fix things. Wilson and Hesbon pushed for higher profits by telling customers that they have paid a certain amount for a new component which is higher than the actual price or indeed when a used component has been put in the product but such financial wrangling does not constitute the "banditry" that Packard found on the part of some "buck-happy repairmen" (130: Packard, 1961). Instead,

in Bomet, like in the communities that Packard describes most repairmen are: "competent, conscientious, and dedicated" (131: Packard, 1961).

Wilson and Hesbon were however disparaging of other mafundi particular those in more remote areas of the county. I was told that these, who could be referred to as village fundi, had less skill, knowledge and experience than those able to operate from the town. One particular village fundi, Baba Nani,[82] would come to Malo Malo at least once a week to consult Wilson and Hesbon on a repair, at times even sub-contracting them to do the repair for him. Part of this came from a pride in their own work: Wilson described Hesbon to me in an interview as "a perfect fundi" while Hebon himself said that he was the best in Bomet for fixing TVs.

It may also be pride that explains the mafundi's response to failure. When repairs failed at Malo Malo it was not seen as a judgement upon the Wilson or Hesbon's skill or expertise but rather the object itself is said to simply be 'broken' (*imevunjika*) or destroyed (*imeharibika*). Mafundi speak of products 'becoming' (*imekuwa*) or 'refusing' (*imekataa).* It is not they that have been defeated but more that the product has not co-operated.

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Being the only white resident in the town my presence at Malo Malo made the clinic more visible than it would otherwise have been. People came at times just to look in at the *mzungu fundi.* My presence also bore an influence on what I saw and some of the narration and conversation offered by Wilson and Hesbon was for my benefit. My presence also altered the physical surroundings of the clinic. A few weeks after my arrival Wilson led a reasonably thorough clear out of the clinic. Although he denied it was the case I had the impression that the clear out had only occurred in order to make more space for me to sit in and observe from behind the counter, not in-front – a space that is reserved for customers and friends to gather. Ironically the deeper I was immersed physically in the clinic the less in the way I would be.

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[82] Wilson and Hesbon's nickname for him, meaning Father Who or Mr So-and-so. His actual name was Koech.

Malo Malo sits between a café to the right and a hardware shop to the left as you look out to the road. The clinic is separated from its neighbours by some thin wooden boarding. This minimal boundary is good for calling through to John in Highway Enterprises (the hardware shop) when in need of parts or to assist a customer who is being sent there. The 'walls' however are not so good at keeping out smoke from the charcoal-fired kitchen at Amboseli Hotel (the café). The smoke comes filtered through a stack of sound systems and woofers that line the right- hand wall, an extension of the sagging shelves on the back wall where the TVs, DVD players and radios live. On the left-hand wall a single bulb directs light on to the workbench below. Under which there is a keyboard, a solar panel and various other products. Higher than the workbench, facing out the open front of the clinic is the counter over which most interactions are had and on which most repairs are made using the much brighter daylight from outside. In the back of the counter are bags of mobile phones and circuitboards. I spent most of my apprenticeship sat on a small stool at the workbench or on a high stool in front of the counter.

Sixteen solar repairs

I worked alongside, underneath, behind and often in-the-way-of Wilson and Hesbon, six days a week from 8 a.m. until 6, 7 or sometimes 8 p.m. I watched as people came in with their radios, TVs, sound systems, mobile phones, hairdryers, fans and other household electronics. I followed the negotiations over what the problem was, its cause, its solution, its cost, the time it would take to repair and watched the repair happen. As I did so, Wilson and Hesbon, would tell me to pass this, open that, solder something here, connect something there, hold that bit, get rid of that one and so on. It was a learning much like Daniel had had at the hands of Harry Burris (see Chapter 1) and, excluding my ethnicity, typical of a Kenyan fundi.

When a solar lantern or home system was brought in for repair I introduced myself to the customer and asked them for their phone number so as to arrange either a home visit or an interview at a later date. Constantly wary of my position within the clinic I worried that these approaches to customers would be a problem for Wilson and Hesbon or that I would be affecting their earnings for the day. However, I soon learnt that the simplicity of solar lanterns, SHS battery units and external panels means they present less of a financial reward for the clinic, often requiring a straightforward replacement of a

button switch or re-soldering of a wire. Their relative infrequency also helped; my interest was not central to daily business.

During my apprenticeship at Malo Malo 16 solar products were brought in. Mercy, Esther, Bii, Willy, Janet, Simon, Martin, Purity, Leonard, Lang'at, Stanley, Christie, Chepuchuk, Samuel, Eliud and another Lang'at brought in their broken solar lanterns and home lighting systems. Each of the 16 customers who came agreed to give me their phone numbers although ultimately I was only able to visit 8 of them at home. This section of the chapter presents elements of these 16 cases of solar repair, focusing on the 8, to show that Wilson, Hesbon, and other mafundi I worked with and was told about, operate as bricoleurs, and so their work, like that of users at home, is a form of bricolage. Mafundi take parts and components from old products and appliances that have been left by previous customers to return other objects to readiness. As for the user at home the fundi's objective is to restore some level of functionality, aesthetic or visual aspects of the product are not important. This and the limits of product and business design decisions of others, made elsewhere, means the form that functionality takes is variable. It is variable for two reasons. Firstly, because, as shown in Chapter 3 and Jackson (borrowing from Tolstoy) says: "All broken technologies are broken in their own way." (228: Jackson, 2013). This necessitates the trial-and-error approach that the fundi follows and means no two repairs are exactly alike. And secondly, the close, personal involvement of the fundi in the process means that any repair is informed by the acquired experiences of that particular fundi and often their own bodies.

The main contrast with repairs at home is that at the clinic most repairs are material repairs. Although there are occasions when mafundi like Wilson and Hesbon return a product untouched perhaps accompanied with advice to a user as to how they might affect their own repair of practice: such as fully charging the product or balancing a cable in a certain way.

Customers who came to the clinic had bought and received their solar products through various means; some from shops in Bomet, some from bigger regional centres like Kericho while others were given them by family members working as far afield as Somalia.

In February 2016 Purity was sent to Bomet with a work colleague's radio from their M-Kopa SHS with the instructions to 'take it to a fundi'. Arriving in town she asked a motorbike taxi rider where she could find a fundi who can fix TVs and radios as I had done on my arrival to

the town. She was directed to our clinic. After quickly opening up the radio, putting his tongue to the circuit board and testing the battery in a phone repaired earlier that morning, Hesbon told Purity that it needed a new IC (integrated circuit). The problem? It is not easy to get a new IC right now. Hesbon told Purity that if she came back with the spare, that is, a similar model of radio he would fix it. And with that Purity left with her unrepaired radio.

Purity told me the story from her perspective in her living room about a month later. She said that later that day a friend had told her that this company, M-Kopa, had a shop in town and so she should go there. When Purity visited the shop she was told that the owner of the product (her colleague) needed to come in and do so with the serial number of his SHS (which is on the main battery unit and not on the radio) at which point they would swap the broken radio for a new one – this kind of replacement-as-repair is discussed in Chapter 6.

What Hesbon had planned to do was a more intricate material repair. He would have taken the specific IC from an existing radio and moved it in to Purity's colleague's radio. I was surprised he sent Purity away as there were a couple of M-Kopa radios lying around in the clinic at the time. The use of components from existing 'stock' and testing parts with other products in the clinic to fix new ones is common to repairs in the clinic. The practice is often referred to as "cannibalising". Similar reusing of components was observed by Callén and Criado in Barcelona and Madrid (Callén and Criado, 2016). It is also a key feature of bricolage, as Lévi-Strauss writes of the bricoleur:

> His first practical step is retrospective. He has to turn back to an already existent set made up of tools and materials, to consider or reconsider what it contains.... He interrogates all the heterogenous objects of which his treasury is composed to discover what each of them could 'signify' and so contribute to the definition of a set which has yet to materialize (18: Lévi-Strauss, 1994)

In practice the consideration, reconsideration and interrogation that Lévi-Strauss describes happens almost instantaneously, at least it appears that way to the customer or the trainee-cum-researcher. Hesbon made the evaluation and diagnosis very quickly. Purity's was not the only case where a lack of parts in the treasury prevented a repair. The volume of solar products brought to the clinic is low, compared to other objects. For instance, on the day Purity came with the solar radio, 7 speakers had been brought in. Greater frequency means more parts available to draw from existing products. And so the treasury of solar spares to draw from is limited. As the volumes of solar products being brought to Malo Malo increases this may well change.

There are signs it already is. During a return trip to Bomet in August and September 2017 I spent a day shadowing each of the other mafundi in the town where I was surprised that in just one day at least one solar product appeared on each occasion. This did not seem a surprise to these mafundi however. When I asked them about this, they said it was relatively common. In our interviews in the same trip Wilson and Hesbon confirmed that they were seeing more and more of solar products at Malo Malo too. It seemed to be an empirical realisation of those millions of products sold through the certified market over the last five years (70: Dalberg Advisors and Lighting Global, 2018).

The alternative to cannibalising from previous or existing products would be to use new parts. But this too is limited. Certified manufacturers do not provide new parts to third parties and nor are there any generic components available, at least not yet. Unlike for Packard's repairmen in 1960s America it is not "the jungle of similar-but-different models" (133; Packard, 1961) that make it difficult for mafundi like Wilson and Hesbon to stock all the variants but the simple fact that currently for off-grid solar products no spare parts are available. Some mafundi do stock more generic new components like ICs, transitors, resistors and capacitors but this requires an investment of capital that most are not able or not willing to make. If a new component was needed at Malo Malo (and was available in the market) Wilson and Hesbon would send customers to buy it from the hardware store – Highway Enterprises – immediately next door to the clinic or to another electronics shop further up the hill.

Were solar parts available perhaps the most in-demand part would be the battery, which, as Chapter 3 explains, is the most common point of product breakdown. Indeed, one survey respondent's landlord who doubled as a fundi in Sirisia, Bungoma County told me that the unavailability of batteries was the biggest limit to his repairs of solar products in the village. Meanwhile Willis at KIRDI told me that:

> even the radio repairer [fundi] can't sort it out because that battery is nowhere to be found in the market.

When visiting all the solar retailers in town, they were often selling generic phone parts and accessories including a large array of different battery types. On my return to Bomet in August 2017 I saw for the first time a spare solar battery. It was for the non-certified but very popular GD Lite system. In Bomet, GD Lite was the most widely sold, and perhaps

best-selling, home system certainly for a cash sale.[83] Whether or not more manufacturers will follow suit or solar parts and batteries will become available as they are for mobile phones remains to be seen.

In addition to batteries Samuel's landlord said a big problem was knowing the number of the ICs. Written in small, faint white writing on the black body of the IC, he uses a magnifying glass to read the numbers. There was no magnifying glass at Malo Malo, Wilson and Hesbon just used their eyes. In a day spent shadowing Yusuf, one of the other mafundi in Bomet I watched as he used a small magnifying glass to check the connections on the back of Greenlight Planet panel. Unfortunately, during the same return trip to Bomet in August and September 2017, Wilson was struggling with a growth near his eye which was impairing his vision and so making his work increasingly difficult.

It is not just the eyes that are important for fundi. Other parts of the body are central to their work: their nose to sniff the end of the soldering iron and check it is hot enough; their fingers to tap the circuit board and feel for current; their ears to listen for the whirr of a TV 'engine' or the *plump* of a woofer. Wilson and Hesbon regularly held things in their mouth or balanced them on the chest while shoulders and thighs became extra work surfaces on which to balance appliances, and wires and cables became temporary necklaces during a repair. Dant's research in vehicle garages in the UK finds a similarly central role for the body and gesture (Dant, 2010). The intimate involvement of the repairman in the repair process again links with bricolage*:*

> [The bricoleur] 'speaks' not only *with* things, …, but also through the medium of things: giving an account of his personality and life by the choices he makes between the limited possibilities. The 'bricoleur' may not ever complete his purpose but he always puts something of himself into it. (21: Lévi-Strauss, 1994)

While Lévi-Strauss is not referring to physical self of the bricoleur's body; the fundi's saliva or breath for instance, the principle holds that repair like bricolage is a very personal project. It is both informed by and constitutive of the person doing it. This putting 'something of himself in to it' is another reason why repair is inconsistent. Not only might a repair make use of previously used parts but it also varies according to who is conducting it.

When Stanley brought his unbranded solar lantern to Malo Malo, Wilson gave it to me to do. Mafundi generally prioritise products according to the amount they can make from a repair, TVs although often a lengthy repair are one of the more profitable appliances

[83] M-Kopa might have had more unit sales on pay-as-you-go (PAYG).

for a fundi. For this reason, solar was rarely a priority. And so it was not just for my interest that Hesbon and Wilson would pass solar jobs, like Stanley's on to me, it was also because there was less money in them, they were less complicated. Stanley, a community health worker, had knocked the lantern off the top of his car when he was cleaning it the day before. Although still functional at first, Stanley had twisted off the top of lantern to re-align the plastic lens over the LED as it had shifted in the fall. But, he told me when I visited him at home a few weeks later, that as he did so, some wires inside became unconnected. Pleased that Wilson had entrusted me with a job I wanted to do it well. But feeling the pressure of his gaze and that of Stanley, my sweaty hands struggled to manipulate the soldering iron, the solder wire and the flimsy, thin wires of the product. Wilson stepped in to resolder the connections, charge Stanley 50 Kenyan shillings and send him on his way. Despite using the same tool it was in Wilson's hands, honed from the experiences of countless comparable repairs over the years that he was able to make the very simple connection very quickly. It is not just the tools and gestures of the body then that make each repair unique but also how that body interacts with external tools: in this case the soldering iron.

The soldering iron is the centrepiece of the fundi'*s* external toolkit and is employed in nearly every repair at the clinic. Unfortunately, when Samuel arrived at the clinic with his SunKing Pro 2 there was no electricity and so no power for the soldering iron. Samuel's story actually starts a few days prior to this however. When Samuel noticed his product was not charging he summoned a local village fundi from the nearby centre – a 50-shilling motorbike ride east of Bomet – to come and fix it. Although able to open the product this fundi could not see what the problem was. His next step was to turn to the connector port where the panel cable is inserted into the lantern but according to Samuel, the fundi broke this. So, when Samuel reached Malo Malo a few days later he had two problems that needed fixing: why the product was not charging and the broken connector pin. Samuel waited on the chance that power might come back. This was not unusual. Customers often wait around to watch as their repairs are done, knowing and fearing that if they do not then other jobs will push them down the list of priority. What was unusual is that Hesbon rewarded Samuel's patience by using a friend's diesel generator to fix his product. Despite power cuts being an almost daily occurrence this was the only time I saw such in my time at the clinic. Although frustrating for Wilson and Hesbon powercuts were more often used as a welcome break allowing time to rest out of sight in a friend's sewing shop two doors

down or to catch up on the odds for the day's football betting. The exception may have been due to Samuel's age and status as a *mzee* (old man); older people are well-respected in Kenyan culture (577: Ogola, 2006). Samuel's experience with the first fundi is not the only time I heard of a fundi creating, rather than solving problems. Several users in the survey had had negative experiences with mafundi either not being able to fix their products, losing parts of the product in the process (such as the rubber insert that holds a stand in place) or simply misplacing the whole product. Even for Samuel's actual repair at Malo Malo he had to return the next day because the product was still not charging. Repair then can be frustrating, repetitive and tiring for the customer. Emotions that come to colour the opinion and reputation of mafundi (see previous section).

The fundi's repair, like the user's in Chapter 4, is limited. Although with different skills, in different settings, the limits of these repairs at the home and in the clinic are because both user and fundi are bricoleurs. The difference at the clinic is that the knowledge, the skills and the tools are there. The physical make-up of solar products is little issue for most mafundi. Their work is limited by the relatively low volumes of solar products next to other electronics: they have less familiarity with solar products and used products to cannibalise for parts are scarce. These two factors are only exacerbated in more rural areas for the village fundi. Hesbon told me in our interview that these village fundi: "They can do redio only".

Such limits however are exactly what makes the repair business one of bricolage. Working from an existing product, using parts of other used products and drawing on their physical selves, their trained gestures and their experience is why the fundi is also a bricoleur:

> the possibilities always remain limited by the particular history of each piece and by those of its features which are already determined by the use for which it was originally intended or the modifications it has undergone for other purposes. The elements which the 'bricoleur' collects and uses are 'pre-constrained' like the constitutive units of myth, the possible combinations of which are restricted by the fact that they are drawn from the language where they already possess a sense which sets a limit on their freedom of manoeuvre. And the decision as to what to put in each place also depends on the possibility of putting a different element there instead, so that each choice which is made will involve a complete reorganization of the structure, which will never be the same as one vaguely imagined (19: Lévi-Strauss, 1994)

Economic repair

The fundi then is a new character in repair studies. The mafundi working to repair TVs, radios and other household electronics in Kenya are increasingly dealing with off-grid solar products. From more of a weekly occurrence in one clinic in 2016 to a near daily occurrence in six clinics across the town in 2017, these products are entirely compatible with the fundi's existing skill set and business model. This is particularly true for non-certified products, where there is no conflicting processes of warranty or authorized repair to navigate.

The fundi is a skilled person, most of the time a man, and overwhelmingly Luo. A key actor within the *jua kali* sector (that Wilson and others described to me as being characterized by 'daily work' and working for yourself) the repairs of off-grid solar products by mafundi are, like at home, limited. Unlike the users mafundi are engaged in more material repairs rather than the repairs of practice that were shown to dominate at home (Chapter 4). Similar to the pragmatism that drives users at home to break the imagined mould the certified market makes of them, the economic drive of the mafundi keeps them fixing albeit within limits. However, unlike at home the limitations are not determined by tools, knowledge or skill but by parts, product design and business design. This is however different than being limited by resources as some have characterised informal repair in Kenya (Holt and Littlewood, 2015). The clinic was full of resources, the limits were not so much material but more structural.

The mafundi I worked with do not struggle against such limits however. They sought only to satisfy the customer at hand, not challenge the complex market chain in which they are both embedded (and marginalised). If anything, Wilson, Hesbon and others were respectful and accepting of political context and their position within it. They would tell customers for instance to return M-Kopa products to the company shop on the other side of town rather than interfere in that particular company's operations. Baba Nani, another fundi I shadowed, told me similar in our interview:

> *Mimi najua sana sheria na mi-mimi nafuatanga ukweli sana sana* (Me I know the law well and I really follow it truthfully)

And so he would refuse to touch what he called the Safaricom systems (in reference to M-Kopa's close partnership with Kenya's leading mobile network provider Safaricom). If

Greenlight Planet keeps its SunKing shop in Bomet long enough the same may well start to happen with their products.

Admittedly the servicing of non-certified products is, if not intentionally, political. In fixing non-certified products the mafundi are by subconsciously acting against those invested in organisations like Lighting Global and GOGLA. But in general the mafundi I learnt from were much more animated by discussions of national politics than engaging in political acts themselves. This is unlike the ingénieur who

> is always trying to make his way out of and go beyond the constraints imposed by a particular state of civilisation while the '*bricoleur*' by inclination or necessity always remains within them. (19: Lévi-Strauss, 1994)

The bricoleur then does not question the context or their position but in accepting it, works to make the best of what is available. A pragmatism that is reminiscent of the actions taken by users at home, as discussed in Chapter 4.

Mafundi also have different motivations than users' pragmatism. Although like users' pragmatism the economic motivation of the mafundi is not currently captured in repair studies literature. Repair scholars point variously to joy (Packard, 1961; Dant, 2010), politics (Lepawsky et al., 2017) and the environment (Houston et al., 2016) as motivating factors for those who fix and tinker. But none of these three motivations were obvious in the work of the mafundi I learnt from. This chapter instead points to the need to support oneself and one's family financially as the reason for repair in Kenya's electrical and electronic repair clinics

When Jackson and Kang (2014) engaged in their 'Scale' project: an installation with artists that reimagined and reconfigured broken and discarded electronic and electrical appliances, they write of how:

> Opening up many of these objects looked and felt less like "opening the black box" in its cold and analytic in sense, and more like opening a present, with all the mystery, excitement and pleasure, the analogy implies. (8; Jackson and Kang, 2014)

While I personally felt this in the clinic and in a separate project connected to my research called the Off-Grid Solar Scorecard,[84] I did not observe the same joy in the mafundi I worked with. Instead the opening, or closing, of an object was given the least attention. It

[42] The Off-Grid Solar Scorecard is a website that scores products according to their design for repairability, recyclability and the availability of service and spare parts. It can be found at www.offgridsolarscorecard.com (Last visited 23rd August 2018).

could be relegated to me or even the customer while attention turned to the next job (or an entirely un-work-related conversation). Hobbyist repair-people such as YouTuber, Big Clive (Big Clive, 2017) or those studied by Callén and Criado may do so for fun and "the pleasure of learning" (19: Callén and Criado, 2016) but for Wilson, Hesbon and their colleagues in Bomet, joy comes from European football (and betting on it), *matumbo* (beef tripe) lunches and in some cases gospel music or alcohol. More commonly expressed or observed emotions were of fatigue from long days and difficult customers, or frustration at difficult repairs.

Other repair scholars understand the act of repair as a political one. Rosner and Ames found that repair is promoted as a path to consumer empowerment (Rosner and Ames, 2014). At times this political agenda is framed in terms of a battle or contest with manufacturers (McLellan, 2013), with objects (Orr, 1996) or against other repair-people (Houston, 2013). But in Bomet mafundi were endlessly more cooperative than combative. The third oft-cited motivation for repair in the literature concerns the environment. Similar to the users of solar rarely citing environmental benefits as the reason for their purchase, the environment was never mentioned by the mafundi I worked with. Rather, their disposal practices (below) suggest a lack of awareness if not disregard for such.

The purpose of the fundi's work is economic: to make money. Wilson and Hesbon fix electronics to provide for their families. A typical day for Wilson and Hesbon might earn them anything from 100 shillings (~$1) to 3500 (~$35) on a really good day. Wilson told me that you never know how the next day will be, a precarity being something regularly associated with the informal sector.

> Now, the characteristic feature of mythical thought, as of 'bricolage' on the practical plane, is that it builds up structured sets, not directly with other structured sets, but by using the remains and debris of events : ..., fossilized evidence of the history of an individual or a society." (21: Lévi-Strauss, 1994)

Working from leftovers the bricoleur (read: fundi) is already working with what others have deemed waste, or superfluous. But through the trial-and-error process that is bricolage, ideas, bits and unused leftovers are themselves left to fall to the floor and be swept away. The next sections explore disposal at the clinic.

Daily sediments

"Repair has its own material legacies and externalities that cannot be tidied away." (55: Houston, 2017)

During a repair, or during the many (and long) waits between repairs, Wilson and Hesbon would use the back of their hand to brush bits of wire, solder, screws and other debris off the workbench or counter on to the floor inside or the ground outside of the clinic. Even a bricoleur cannot re-use everything. First thing every morning on opening the clinic one of Wilson, Hesbon, Duncan (a friend who runs a general store a few doors down from the clinic), or myself would sweep the floor of the clinic, the previous day's debris joining the bits and pieces in the shallow ditch outside. One day in February 2016, however I arrived at the clinic in the morning to see Wilson lightly tossing a series of things from the shelves to the floor. He stopped to put his fleece back on in order to keep the dust off of his Arsenal football shirt. I asked him what was going on and he told me that we were having a clear out. Wilson told me to put the stuff he was throwing on to the floor in to plastic bags and then put the bags out the front of the clinic. I crouched down to start collecting the bits of plastic, wire, circuit boards, and batteries. That day we only threw out two identifiable appliances: an iron and a television. The latter of which Wilson told me to first take out its circuit board: we would hold on to that.

The rest of the chapter describes where waste moves from Malo Malo and what happens to it. It argues that like at home, most broken down products are held on to in the clinic. Waste does not generally leave the clinic in the form of recognisable electrical appliances and electronic products, the kind that are often pictured in studies of e-waste (e.g. BAN and SVTC, 2002; Basel Action Network, 2005), but is instead closer to what sociologist Jennifer Gabrys calls "sediments" (vi: Gabrys, 2011).

I did not put any obvious solar waste in the bags that day. Admittedly it would be hard to tell at this sedimentary level if a fraction of wire or a shard of plastic that I put in the bags had come from a solar product or from a radio. Given the size of solar products, their constituent components, and their minimal financial value to the business of the clinic however it can be assumed they have been disposed of in similar clear outs in the past, and will be in the future. In leaving the clinic these sediments having broken down in relation to their previous form as an electronic good form new relationships. And in doing so, they move out of the gap (which at the clinic is on the shelves and in piles around the walls),

leave the solar assemblage and enter into new assemblages of waste, materials, chemicals and elements.

Shadron and the opportunistic scavenger

Not long after I had placed the bags out the front Shadron came by. I had seen Shadron around before. He was often wandering around town with a white plastic sack over his shoulder, the kind also used to transport commodities like charcoal and carrots around the country. After a brief exchange with Wilson he emptied the bags I had just filled on to the ground in front of the clinic and began to rifle through the pile. He was looking for any metal or 'scrape' (a Kenyanisation of the English 'scrap'). He told me with pride that he was recycling and asked me if people did this in my country.[85] I explained that yes, we do, although it looks somewhat different. In 'my country' - the UK - recycling is organised, if not conducted, by local government authorities. Shadron meanwhile works for himself. He complained audibly that there was no metal. After smashing off the bottom of the iron with a metal bar he had carried with him, Shadron put most of the stuff back in the bags. Some of the smallest bits remained on the ground akin to that left after the daily morning sweep-out of the clinic floor on to the same patch of ground. These would be found by children in the days to come and, like at home, taken (if only temporarily) as toys. Both that taken to play with and that left behind would ultimately be trod in to the dirt or tossed in to bushes and waterways to be sniffed at and nibbled by roaming dogs or grazing goats. Having separated the metal that he wanted Shadron took the three bags up to the bin area directly in front of the clinic, just off of the road. He took a hanging scale out of his pocket and weighed the metal he had extracted in his sack in front of Wilson. Shadron said it was 4kg, Wilson said it was more. They both turned to me to check. I looked, and, trying to please both parties, said it was slightly over 4kg. Shadron paid 50 shillings ($0.49[86]) for the metal and went on his way.

This section shows that although there is professional engagement with waste through Shadron's work, there is also non-professional involvement as children and passers-by come to rifle through that which Shadron cannot make money from.

[85] Shadron's awareness that his work brought benefits for the planet was not matched by the *mafundi* who, like Houston's informants in Kampala, showed little concern for the environmental impacts, positive or negative, of their work.

[86] Based on a conversion for the currency rate on 4th February 2016 (the day of the clearout) as given at www.xe.com (Last visited on 9th July 2018).

Methodologically it suggests a need not just to follow the thing, but watch it too, as it is only through such observation that some more liminal actors come in to view.

Although Shadron describes himself as a recycler his work does not involve much material transformation, his main work is to collect materials in to the one place. About seven weeks later Shadron took me down to the store on the eastern edge of the town centre where he brings all of his metal. At the end of a narrow path we came to a wooden structure with chicken wire round the sides that was half-full of various shades of brown and grey paint cans, cooking pans, roofing sheets and lots of indiscernible pieces of metal. Shadron told me that a truck comes by about once a month to empty this store.

In a return trip to Bomet a year later I arranged with Shadron to shadow him for a day. When I arrived at the path down to Shadron's store he was not there but there was a truck reversed up to the path with three young men stood on the back. Then I noticed there were five younger boys ferrying white sacks of metal from the store and throwing them on to the back of the truck where the older guys were ripping and cutting the bags open to empty out the metal. Waiting for Shadron to arrive I sat and watched the booming, crashing, rustling and cracking as the metal was stacked, slotted and organised to maximise the use of the space. Paul, who sells flour, grain and milk from the shop that is next to the path down to the metal store seemed to be supervising the operation. He was watching in particular for brass, aluminium and tin, non-ferrous metals that sell for more than the iron and steel that make up the bulk of the scrape that was being loaded on to the truck. Keeping these to one side Paul told me: "*Hii ni jackpot*" (This is the jackpot!).

On the day of the clear out when I had first spoken to Shadron the year before I had seen a different, less strategic kind of siphoning than Paul's. As I looked out from the clinic at the three bags Shadron had put by the roadside I saw some people take interest in their contents. Steadily at first, one or two men flicked through the bags and took a few things. Soon this increased to a veritable crowd of 10 people searching through the now up-turned bags (fig. 5.2) and taking bits and pieces until, less than half an hour later, there was barely anything left at all. After the adults had taken their share some children began to play through the remainders. Even the next day children were playing with the plastic that was left. By the time a green-coated County Government employee tasked with waste management in the town, passed by, there was very little left. He raked the pile back together and moved on. It would be taken by some of his colleagues to the dump on the south-western edge of town the following morning.

Figure 5.2 Passers-by scavenge the leftovers of Shadron's leftovers at the bin area in front of the clinic (Author's image February 2016)

These passers-by are evidence of the loops within Bomet's waste economy, some of these things will now be taken home and move through processes similar to that described in Chapter 4, others may be taken to a fundi in the village for sale or perhaps another scrap dealer elsewhere. The movement of people and goods within this research do not follow then the linear path charted by this thesis. These loops support Hetherington's argument that waste can return (Hetherington, 2004) and, demonstrating the transitory nature of waste also fit with Josh Reno's call to see waste "as a temporary set of things in between forms of life" (20: Reno, 2014). The movement from consumption to disposal is not linear.

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My three months in the clinic were a constant balance between fitting in as a fundi and being present as a researcher. This balance manifested itself in the tension between listening and asking. I did not go and ask the crowd of 'scavengers' around the bin area where they were taking these bits and pieces or why because, it being early on in my 'training', I was still establishing my rapport with, and legimitacy amongst, Wilson, Hesbon, and their friends. I worried that approaching these passers-by would jeopardise that. This

was less the case when observing waste collection where my lack of experience, the more visible nature of the work (moving through town rather than inside a workshop), and the shorter term of observations made me both more conspicuous and the likelihood of being accepted on any meaningful level, even more remote.

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Landfill and roadside incineration

Although not the case on this particular occasion, after the scavenging has been done, and before the County Government arrives, the waste in the bin area at the side of the road is sometimes burnt. This is not done directly by Wilson or Hesbon but by others who share the bin area with them – like the café immediately next door or the fruit and vegetable sellers in front of the clinic to the left. The bin areas are communal and in the evenings many of them are set on fire in order to keep dogs and other pest animals away overnight from the organic waste (banana peel, mango skin *et cetera*) that is left there each day. I use the phrase 'bin area' as some of the green metal bins are more erect, and so discernible, than others. What is more they have longer become signifiers of where to put waste rather than containers in which to put it. The bin in the above anecdote is one of the most dilapidated that line the north-western side of the main road through Bomet.

When I returned to Bomet in 2017 I wanted to try and spend some time shadowing those wearing the green labcoats as they did their rounds. For this I went through the County Government offices, across the road from Malo Malo. After being passed a few numbers, told to go to a few different offices and to come back another time I ended up speaking to Nelly, from the Environment Department of the County Government. When I mentioned the possibility of doing a round *with* the waste collectors I had seen wearing the green coats the year before she advised that we first did an interview with her and Zaheer, the supervisor of the Urban Planning team.

In the interview Zaheer explained that there are 55 'casuals' in his team who rotate around five sections: drain clearing, garbage collection, garbage transportation, slashing (of grass, trees and bushes), and weeding (flowers). All these 55 casuals included both men and women the next day when I split my time between the garbage collection and garbage transportation rotations I was only with men. I spent the day raking rubbish together, pushing it on to ripped-open sacks like the one Shadron carries, throwing this in to a trailer that was then driven by a tractor down to the dump.

I noticed that it was not just the bins that are dilapidated in the town's waste infrastructure. The casuals were sharing gloves in pairs and rakes between five. Those without rakes picked up branches or broke off bits of wood to spear or scrape the rubbish together into one pile. Zaheer had commented on the shortage of equipment, particularly the need for another truck, during our interview.

I also noticed that it was not just Malo Malo's preliminary contribution to the town's waste stream that loses bits and pieces to the ground. Sediments are also lost in the process of collection. The casuals scrape the recently consolidated piles on to open sacks that are laid on the ground and held down with one person at each end: a foot on the corner furthest from the trailer and a hand holding up the opposite edge to form a sort of fabric dustpan, while a third pushes the waste on to it. Some waste does not reach the sack whilst some goes under or round the sides. When full the sack fabric is folded corner to corner and swung up to two guys stood in the trailer to arrange as I had seen the metal dealers do. And in this motion some bits fall out the sides and fall back to the ground. Although there is some siphoning by the waste collectors most of it is involuntary as bits and parts fall away or are trodden in to the dirt, or left behind when a dump to which they deliver moves location: this has happened in Bomet three times in recent years.

The waste being moved was mainly from commercial properties but some residential flats too. It mainly consisted of plastic bags, straws and food packaging, speckled with the metal caps of soft drinks. I did not see much electronic stuff in that we were putting on to the trailer, other than a bulb and a CD. However, this is the stream that waste from the shops selling solar products and the other repair clinics around town would make their way in to. Indeed, our first stop on the day I was with Zaheer and the casuals was a large pile at the back of the bus station between Yusuf, David and Rono's clinics – three of the other *mafundi wa TV na redio* in the town. While for the retailers this is mainly marketing materials (fig. 5.3) and packaging, the sediments of new products will also enter this system. Although some retailers will be sending back products to manufacturers and distributors in Nairobi (see Chapter 6), others will be in these roadside piles around Bomet. In an interview with David formerly of Faulu for instance when I asked where the cannibalised bits of EcoSmart products went, he told me: "Those ones we disposed of them."

Figure 5.3 An M-Kopa flyer in one of the waste piles around town (Author's image, September 2017)

After five hours collecting we headed to the dump. The dump has moved places several times in recent years, leaving sediments each time. In addition then to the deliberate siphoning of opportunists, much waste falls away; off sacks, under trailers and is left behind when entire dumps are moved. As demonstrated in Chapter 4, if studies of waste concentrate on sites of waste rather than the journeys to those sites then scholars miss the smaller sediments that are scattered along the way.

Holding on

People sometimes came to the clinic looking to sell old electronics to Wilson and Hesbon. I never saw either of them buy. They had enough 'stock' coming in from their own customers without giving custom to others. What is more, investing in used goods would have been inconsistent with the governing business ethos of the clinic - to minimise expenditure. Indeed, the clinic was so full of appliances in various states of wholeness and functionality, that Wilson and Hesbon regularly complained about how no one came back to collect their objects, or that people would come back after such a long time it was

impossible to know which object was theirs or for anyone to remember what the problem had been in the first place. Unclaimed objects like the TV or the iron in the above episode will occasionally make their way out of the clinic, to make space. But the usable part, like a motherboard, which is much smaller than the whole, will live longer in the clinic and might make its way out in parts (an IC in a different TV) or as broken bits of circuit board (squashed by heavier appliances or stood on when accidentally knocked to the clinic floor).

Unlike with the users at home there is little uncertainty or guilt in the disposal practices of mafundi instead, linked to their economic preoccupation with repair, they dispose when things have no economic value to them or when their economic value is outweighed by the need for space for other perhaps new but certainly more useful products. None of the mafundi in Bomet expressed any concern for the environment in their work or disposal practices, nor were they especially interested in where their waste goes next. Wilson only wanted more money from scrap collectors like Shadron.

While the above episode focused on that which was removed from the clinic, it should be emphasised that disposal at the clinic is dominated by the act of holding on. Wilson used this clear out as a chance to straighten up the clinic; he put DVD players next to each other on the shelves on the back wall, re-stacked the TVs on the left-hand wall, lined up the woofers under the main bench and dropped phones in a plastic bag under the customer-facing counter. The post-clearout clinic, while tidier, looked as full as it had done before. It looked so full I wondered where the stuff we had bagged up had even come from.

Deliberate and involuntary siphoning

None of the single days observing the 6 other mafundi in Bomet coincided with a clear-out as thorough as described above. In a day with Yusuf however he was sorting his clinic out as he wanted to stop doing repair and just to sell spare parts and components instead. In terms of conscious disposal it was mainly cardboard and plastic packaging that Yusuf left by the roadside for later collection by the County Government (fig. 5.4) but even clearer than out the front of Malo Malo one could see the sediments of independent repair work out the front of Yusuf's clinic including bits of wire, ICs, old plastic radio tuning dials (fig. 5.4).

Figure 5.4 Sediments and the day's disposed rubbish from Yusuf's sort out. (Author's image, August 2017)

This chapter has described how the daily sediments of the clinic are swept out to be trodden in to the ground, washed away by rains, picked up by children or nibbled at by animals.

> this sediment of electronic and plastic defies our ability to reclaim it (or to stop it becoming such sediment). This left over peripheral matter; in the ground, in storage, and in domestic clutter, we might regard as 'the ghost of the machine'. (219: Maycroft, 2015)

Less frequently, bigger sized pieces are removed which are first sorted for their metal content, then sorted by curious passers-by, before being burnt or dumped by county government 'casuals'. But most waste waits in the clinic. It sits in the gap identified at home (Chapter 4). Gregson et al. use the term "transitional goods" (683; Gregson et al, 2007) to describe this waiting. The transitional goods of the clinic are waiting: to be dismantled (in the repairs process), to be collected (by the previous owner), to be sold (as scrap metal), to be taken (by passers-by) or, failing that, to be dumped (by the County Government) or burnt. It is through this suite of practices (from dismantling to dumping)

that transitional goods can break down to the sedimentary level or be looped back through as a passer-by takes a circuit board to another fundi to try and sell it there.

The focus of e-waste scholarship on legislation (Nnorom and Osibanjo, 2008; Lepawsky, 2012), the urban dump (Reno, 2015; Rifat et al., 2016), or transboundary movements (Lepawsky and McNabb, 2010; Lepawsky and Mather, 2011), diverts attention from that which is swept away, siphoned off and falls out, after use and before reaching sites of consolidation. Without a broader understanding of what e-waste is (at times in very small pieces) then we risk under-estimating the scope and scale of it that which is being domestically produced in countries like Kenya. Without a broader understanding of where (in rural areas) e-waste is, the intermediary scavenger (the interested passer-by or the imaginative child) is invisible. These are not people whose work falls easily under formal (like the County Government employees) or informal (like Shadron) labels. These are not career scavengers nor are they scavenging for survival but rather they are opportunistic. In addition to hoped-for financial gain the opportunist might benefit in other ways like fun or putting their siphoned scrape to some as yet unknown future use in their own home. Although scavengers appear in Rathje and Murphy's work where:

> Even the durables that do finally get thrown away - left out at night for disposal - are likely to be subject to the attention of alley scavengers and scavengers at landfills. (191: Rathje and Murphy, 2001).

the idea of siphoning small amounts of waste with no immediate purpose or application for them is a set of actions and an actor that is yet to be closely explored in the literature. The category is also found in the channels of waste that flow from company offices, workshops and warehouses. It is to these locations that the thesis now turns.

Chapter Six

Repair and disposal at the company

Satisfying customers, saving costs and keeping consistent

Before talking about after-sales processes nearly all company representatives prefaced their comments with the warning or insistence that problems with their products were rare or low in number. Volumes are small, Ramin, at Orb Energy, told me: "cases are not many that's why it's easy for now at least". Interviewees repeatedly stressed a confidence in their products. This confidence manifests itself in a lack of priority given to questions of after-sales service. When after-sales service is required however there was also confidence in those processes and in the capability of company-employed technicians. While users and mafundi are derided (chapters 4 and 5) technicians are granted competency despite, as this chapter will show, similarities with mafundi in their training and practice. Company confidence extended to the types of problems too - the ones the company are responsible for are typically small and the majority of breakdowns were said to be the faults of users, mafundi and occasionally retailers or sales agents.

Although similarities are found with how repairs are done at home and in the clinic the scale of operations and geographies is much greater here than in either of the other locations. Like in the clinic keeping costs down is key but this is balanced with keeping customers satisfied and maintaining a brand image which is based on consistent quality. This three-way trade off means that the most common response to breakdown at the company level is to replace. Companies often replace whole products (or parts of them) rather than enact material repairs or repairs of practice. Another key difference from the home and the clinic is the attempt to implement and follow a controllable, standardised process. Despite a couple of interviewees narrating a hierarchy of steps:

> I'm all you know, recycle, reuse, so if we, we can repair, then we will repair, if we can re-use, we will re-use, if we then have to recycle, we'll recycle that's sort of what we try.

This was contradicted in observations where company processes were bent and flexibility was common. The chapter suggests that this flexibility is due to the inherent inconsistency

of repair which resists attempts at rationalisation. Despite efforts to adopt an ingénieur's approach to after-sales, in practice company processes conform more to bricolage.

The data in this chapter comes from interviews with company representatives, observations with company technicians, observations with waste collectors and a site visit to an e-waste recycling facility.

A defined repair process was prominent in both interviews with company representatives and observations of after-sales operations. Reflecting this, the chapter is structured along similar lines. It begins first by looking at the technician: their training, recruitment, the space where they work and the tools they work with. The next section looks at the first troubleshooting which often takes place remotely, or at least in the rural area. The chapter then discusses the journey of products from the site of use (predominantly homes in rural areas) to the company premises (office, warehouse or workshop). Once there, attention turns to a more technical diagnosis of the product and to understanding its breakdown. The chapter suggests that although repair at the company is more a case of replacement (the change is neither of practice or material) similar motivations are observed in a mix of both the pragmatism of the home and the financial imperative of the clinic. The chapter then turns to other responses to breakdown, starting with the gifting of broken down products or their refurbishing for use in charitable projects. Other products make their way in to the local (now urban) waste stream while others still are waiting in warehouses. The penultimate section of the chapter visits a recycling facility which several of the certified companies have partnered with. The chapter concludes that despite efforts to the contrary company repair is bricolage and that disposal from company premises, although less characterised by sediments is still prefaced by waiting.

The polyvalent technician

Over lunch under a canvas roof in a roadside café, I asked Benson, a technician at Sollatek, what he would do that evening, after work. He told me he would go to his '*jua kali* shop' which is on the way back to town. On evenings and at weekends Benson operates as a *fundi wa stima* (electrician). Despite working full-time at Sollatek (a third party distributor of certified solar products) for 13 years, Benson continues to supplement his salary with self-employed work doing electrical installations and wiring. He told me this halfway through the day I spent shadowing him in the workshop at the Sollatek headquarters in Mombasa in December 2016. The overlap between Benson's formal and informal work

extends further in that he normally brings his own tools to work because, he told me, the company does not buy good ones or replace old ones.

Benson is one of eight technicians that I shadowed.[87] I also observed Alvin, Amos, George, Henry, Julius, Stephen and Frank at their places of work for certified manufacturers and distributors. In these other workshops and warehouses I encountered similar overlaps between the fundi and technician, between the formal sector and the informal. I heard of technicians who are only drafted in when repairs are needed or who previously worked (and originally trained) as mafundi. I watched as technicians worked out with company processes to help their 'brother' or earn some side income direct from the customer. Similar to both the categories of user (Chapter 4) and fundi (Chapter 5) the technician is not a singular identity. The technician is however of a single gender: male. Although I did see a female technician at Orb Energy this was an exception. Professional repair, like in the clinic, remains a preserve of men's activity. Typically, survey respondents also referred to technicians as men. The only time an interviewee used the female prefix was to describe a customer care representative at the call centre. Indeed, the customer care team at Greenlight Planet were mainly women, while at SunnyMoney they were exclusively so (see fig. 6.4). Unlike the fundi there is no dominant or shared ethnicity amongst technicians.

Technician is the title given in some solar companies to describe the employee who works primarily on after-sales processes, particularly warranty claims. Similar to the fundi and user categories, other terms were encountered such as engineer. I avoid engineer here to avoid confusion with the dichotomy Lévi-Strauss sets up between the bricoleur and the ingénieur (engineer; Lévi-Strauss, 1994). It is people outside of Kenya: product designers and software engineers that make the kind of decisions that correspond to Lévi-Strauss' ingénieur.

In fact, as this chapter will show, the company-employed technicians are closer to being bricoleurs than ingénieurs. Although the work setting is different from the clinic: the tools available, the space they work in, the hours they work, the salary they take home et cetera, the actual work they do is still bricolage. The technicians are not able to alter the product's initial design as an ingénieur would. Instead like the fundi the technician works

[87] Although interviews were conducted with 14 companies in total, the repair operations of other companies were not observed for various reasons: two companies did not have any repair operation to observe, two did not allow access, one closed down and with another it was not possible to arrange a visit.

within pre-existing constraints created by an engineer elsewhere, normally the US or Europe.

The role of company technicians is polyvalent. In addition to their primary responsibilities within repair or after-sales operations, technicians are often assigned, or voluntarily take on, tasks in I.T., logistics or catering. This section of the chapter outlines two factors that create this polyvalence: their recruitment and training, and their space of work. Several of the technicians I shadowed had gained their employment at the company through a personal (even familial) contact. Others had first come in on a one-off, or 'casual' basis and later graduated to a full-time role. At some companies the technicians either have no dedicated space to work in, or they work from a small corner, at times using their own tools. It is argued that the polyvalent technician is the result of companies' desire to minimise costs and of the lack of priority assigned to after-sales activities.

When I arrived at the Sollatek headquarters in Mombasa to spend a day shadowing the workshop team I was first assigned to Shadrack. The person who would be working on the off-grid products that day (Benson) was out at an installation of a battery-based solar system and would not be in until a bit later. So for the first hour and a half of the day I stuck KEBS Import Standardisation Mark (ISM) stickers on to products. Shadrack showed me how to open the cardboard boxes using a craft knife and apply the stickers to rows of new Voltlights (fig. 6.1) that would be sent out to retailers later that day.

Figure 6.1 A box of Voltlight products in the middle of ISM sticker application (Author's image, December 2016)

I had done this same task during a day at d.light's warehouse in Nairobi too. The proximity of repair to logistics means technicians are often involved in preparing new shipments of products as well as receiving ones returned from customers.

A somewhat monotonous task, Shadrack and I spoke about my research, my views on Mombasa and how I saw Kenya compared to the UK – a topic I was asked about frequently. In breaks in our conversation I looked around at what the others in the workshop were doing: fixing inverters, dealing with walk-in customers and arranging some other boxes for a delivery. I caught sight of a noticeboard, on which there was a schedule

for the year. It showed the four-man workshop team as rotating monthly round four tasks including repair, quality control, and rework. I saw a similar schedule on the wall of the Powerpoint workshop in Nairobi a couple of days later. In both cases the schedule did not appear to be followed strictly. Indeed, at Powerpoint the weekly schedule on the whiteboard was empty bar the names of the technicians and the days of the week. The point here is that technicians move through different tasks, ranging from taping up cardboard boxes to re-working circuit boards and that having processes in place does not necessarily mean they are followed. Jared, the head of Reverse Logistics at M-Kopa told me:

> we are a team of around 5 guys. And each and every person has his or her duty but you can always do anything, we are all rounded.

Indeed, other technicians I shadowed would do the run to get tea and *mandazi* (a deep-fried bread snack) every morning, arrange lunch for the office, collect and deliver parcels around town or help colleagues with technical issues on their mobile phones and laptops.

Some of this polyvalence could stem from the time technicians have available to do these other activities. In interviews managers and supervisors of operations repeatedly asserted that there are 'not so many' returned products. Technicians then might often be free to attend to other tasks. Another reading of this polyvalence is that the technician's work is not highly regarded or paid much attention by company management and so they are left to administer various other tasks too.

One can find both readings: a lack of need and a lack of priority, in the recruitment of technicians. Several technicians I shadowed had been recruited through informal or casual means. Alvin, the technician at Sunlar for instance had been hired through a personal connection to Titus and Geoffrey, the two brothers that run the company. Alvin used to live on the same compound as them. While Amos, a technician at d.light had been recommended by his neighbour who was already working at the company when Wilson, the workshop manager, had asked his colleagues for young guys who are "sharp" and "learn quickly". Wilson had been looking for what are called 'casuals' to come in and work on two specific, short-term projects. Having excelled in these one-off arrangements Amos was invited to stick around. Julius made similar use of casual labour for his work at the Greenlight Planet warehouse. These informal recruitment processes reflecting possibly the lack of focus on the area *or* a lack of need due to the low volumes of products to be serviced.

Training is similar: Amos had learnt by watching Wilson while Alvin, like Hesbon, had taught himself as a schoolchild. When I visited EcoSmart in September 2017, Stephen, who heads up finance for the company, was managing the replacements and repairs himself whenever he had time. He had been trained to do so by Odhiambo a (Luo) fundi that EcoSmart previously contracted in to service their products. In an interview with Stephen's boss, Simon, the year before, I had been told that because EcoSmart did not have products being returned on a daily basis, they did not want to hire somebody on a daily basis to deal with them. Unlike Walid's team of 4 at Sollatek or Jared's team of 5 at M-Kopa then some have little to no (e.g. Jua Energy and Philips) technical presence in the country.

The variations in roles is closely reflected in or perhaps connected to the space technicians work in and from. Part of the reason I was involved in the labelling of products on days at Sollatek and d.light was also down to space. Repair is often next to logistics. Meanwhile, during the day I shadowed Julius he got drafted in to help with IT issues because he is based at the main office, and not down at the warehouse. Julius told me he prefers to work from the main office because the internet is better there but it does mean his product responsibilities are relegated to the balcony (fig. 6.2). Meanwhile at SunnyMoney, space was at even more of a premium; George worked from the board room (fig. 6.3) and some stock was kept in the office bathroom.

Figure 6.2 The table on the balcony where Julius tests and repairs Greenlight Planet products (Author's image, September 2016)

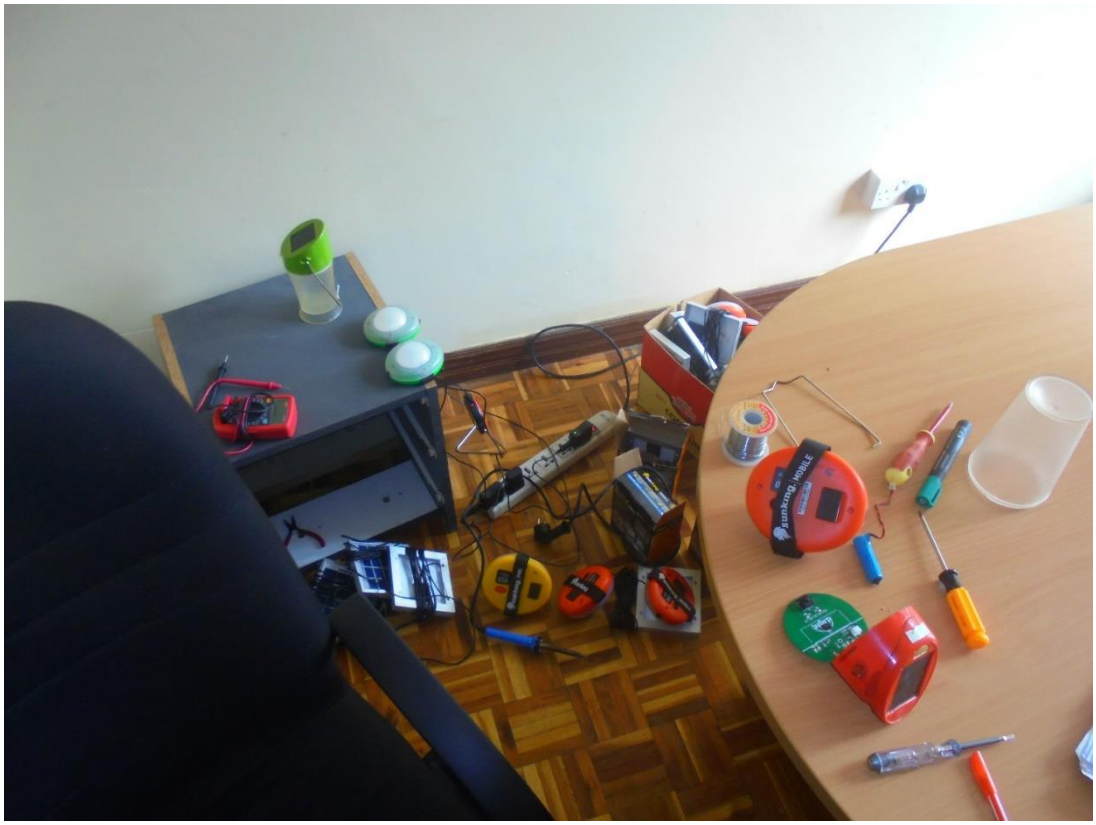

Figure 6.3 George's workspace in the SunnyMoney boardroom (Author's image, October 2016)

So while this chapter, and other parts of the thesis make reference to workshops or warehouses these can look very different. Most often it is a table in the corner although M-Kopa's sizeable repair operation had a separate room as did Sollatek and Powerpoint.[88] For the latter two this is likely the result of their longer history and their engagement with product types beyond off-grid solar products including inverters, charge controllers, batteries and solar water heating systems.

Having a dedicated space for repair did not necessarily mean that the equipment, materials or tools were provided to match however. Over lunch Benson was critical of the tools provided by his employer so he said he normally brought his own. While at the end of the first day shadowing Julius he told me that he labels his pens and hides away his screwdrivers as otherwise they go missing. At d.light the knife used to open boxes was a blade of metal wrapped with a rubber band at one end to act as a handle.

The importance of personal connections through family or where one lives and training on-the-job are two elements that are remarkably similar to the fundi model described in Chapter 5. The space and tools afforded to technicians could still be read as both a disregard or a reflection of the lack of requirement. Yet the at-capacity nature of these spaces with boxes and desks overflowing, again akin to the fundi model, suggests there are products to be serviced lending weight to the view of the technicians' polyvalence as an indication of ignorance rather than strategic response. The apparent unimportance of the technician to the company is reflected in their main repair tasks as well: they are assigned relatively simple work, largely to replace components or whole products after testing. It is to this 'simple' work that the chapter now turns.

First troubleshooting and delivery

For companies and organisations in the certified market a supreme confidence in the technical capacity of their products (perhaps partly a result of the Lighting Global certification) and a certain, widely shared understanding of the user, discussed in Chapter 4, means that the first step in dealing with breakdown is to decide whether a problem is 'real' – the alternative being that the user has not been using the product 'correctly' and so, in the company's view, there is no problem. It is only in the case of 'real' problems (variously referred to as 'actual', 'big', 'complex', 'major', 'technical' or 'internal') that

[88] M-Kopa's repair and after-sales operations have grown so much that they have since been outsourced to a separate facility in Naivasha. The facility, owned and run by Solinc, manufacture solar panels and also assemble SHSs for Fosera, another certified brand.

products need to be sent on to the main company premises. In all but two cases the company head office or headquarters are in Nairobi.[89] The first diagnosis, or troubleshooting as interviewees more commonly referred to it, occurs over the phone or in person when a user (referred to variably by interviewees as the client or customer) takes a product to a sales agent or sales point. The first troubleshooting then is performed by a retailer, sales agent or customer care representative.

This section of the chapter suggests that assigning technical responsibilities to sales staff or remotely via a call centre reflects a general lack of importance ascribed by certified actors to after-sales activities and a lack of specialisation in job roles. Interviewees talk confidently of their sales staff's training and capabilities to perform over-the-phone and in-person troubleshooting. Yet many products make it past the first troubleshooting that, according to the process, should not, undermining such confidence. There are however acknowledged limits to the sales staff's capabilities - field staff are not able to deal with 'real' problems. The outcome of this first troubleshoot then is either to advise the user on correct usage of the product or to send it on to the main company premises.

I met George, of Tropikal Brands, in September 2016. Part way through our interview in a Nairobi coffee shop, George answered his phone. I paused my audio recorder and tried not to listen as George continued his new conversation opposite me. It was one of his sales agents who had a customer complaining of a faulty product, George told me after he ended the call. He said his sales agent will now put the customer in touch with George directly and he will talk the customer through how to test the product. If they cannot solve the problem that way, George told me, they will send the product to him in Nairobi. Tropikal Brands do not operate a call centre as such and so the first troubleshooting takes place on a more ad-hoc basis as I observed with George. For other brands however such queries come through a designated call centre (fig. 6.4).

[89] Sollatek's headquarters are in Mombasa while Trony's base in Kenya is in Kitale in the western region.

Figure 6.4 The call centre at SunnyMoney Kenya head office in Nairobi (Author's image, October 2014)

Call centre staff will normally first give guidance over the phone. This is typically regarding things such as the position of the panel (in direct sunlight), the cleanliness of the panel (not covered in dirt or dust) and the charging of the battery (either too rapid a discharge or not a long enough recharge). Anthony (d.light) told me with confidence that: "more often than not you'll be able to get your result" through that process. If not then call centre staff put the user in contact with the closest agent, ask the user to return it to the shop where they bought it, the branch of a partner such as a bank or MFI or direct them to the nearest service centre.

At these physical points of sale a similar process takes place in person. Interviewees all emphasised the training given to their regional or field sales staff to perform 'initial' or 'basic' troubleshooting. Although Gijs, like Anthony, stressed the technical nature of this training, they at the same time told me the assessment required is a basic one. Largely this troubleshooting consists of checking the battery is charging ok.

Responses at the point of sale or service centre are either to charge the product, advise on 'proper' usage, or issue a replacement product or spare part. EcoSmart and Omnivoltaic, for instance, told me they provide battery boosters to their partners around

the country to assist in cases of extreme or deep discharge, George also said that his retailers can charge products for customers from the grid (similar to seen in Chapter 4). If the battery is ok then guidance is given, as over the phone, regarding 'correct' charging of the product. Ramin estimated that 75% cases can be resolved at this first troubleshooting because:

> [the] issue is not technical failure it's basically customer usage related: either they're not charging it daily or are they are over-using the system, it's really how they use it, those type of concerns you know our engineers should be able to address.

Sometimes replacements are given at this point: for some, like d.light, this would be a whole new product for others, like Barefoot Power or Tropikal Brands (Philips), they would replace the battery. This would be largely based on a visual check that the product has not been damaged or tampered with. But George and others lamented the fact that some retailers or sales agents will prematurely replace the product, or part of it (i.e. the battery) when the problem was only that the product was not properly charged. Despite confidence in the training given to regional staff to make these decisions it appears that the 'correct' decision is not always made.

Such disconnects can have material consequences. Instead of using new parts for instance George said that retailers of Philips products will scavenge new components from whole products. This practice occurred at several companies. David for instance told me that:

> every time somebody would have a problem with the product they [Faulu staff] would scavenge the stock that is there. If somebody says my panel is not working they'll pick a panel from a new product since the products are there.

But like Tropikal Brand's partners, Faulu found that many branches were scavenging these components to repair products that did not have real problems. David told me that in the first year Faulu wrote off "a significant percentage" of their stock due to this practice. He explained that although branches would have 30 products on their records "You find 10 products that have components missing which you can't sell." In order to address this, while avoiding the higher taxation on importing spare parts, Gijs said that distributors for

Barefoot Power will deliberately order a few extra products and "then pilferage on those systems."[90]

After this first troubleshooting, those that have a "real" problem, and the already replaced parts or whole products, are sent on to service centres which are mainly in Nairobi. Most of the certified actors see the first troubleshoot as a form of triage aiming to ensure that products sent back to the after-sales team in Nairobi "really" have problems. Interviewees expressed doubts about their field staff's ability to perform any actual repairwork beyond the initial diagnosis, opting to perform actual repairs centrally where they can control it better and they have the resources and capability to deal with real problems. Martin for instance said that Greenlight Planet do not want component level repair at their service centres because it is "risky still for them [the technicians] to do something wrong.".

Even where more distributed service models were in operation such as for Orb Energy and One Degree Solar, who have both previously run service centres around the country, greater capability was assigned to and associated with Nairobi than regional sites. Ramin said that most of the time products are returned to Nairobi

> because you know even, even in the shops their availability of, of, their sophistication…, to do fixing and the checking is not as big as here in Nairobi.

Ramin said that at the service centres:

> they can do everything when it comes to checking it, checking the, charging the battery, discharging it, seeing if the battery is working, testing if the module is working by putting it in the light, checking if the lights works, those type of things but when it really comes to electronics we do it in Nairobi.

'Electronics' for Ramin meant if a product requires "soldering on the PCB or, you know, things like that". It is not just the user (see Chapter 4) or the fundi (see Chapter 5) whose abilities are questioned then but company employees too.

The responsibility for moving products the first step from the home to the company (sales) representative is the user's. This next stage from regional (sales) representative to the company headquarters or main offices it organised by the company itself, their representative (in case of a partnership) or more often a courier service. On rare occasions

[90] In the East African Community (EAC) home systems are exempt of tax, as are solar panels, but spare parts and accessories such as cables, controllers, batteries et cetera are all charged with VAT (41: EAC, 2016). See Chapter 2 for more on this.

products are taken directly to company headquarters by users. Julius spoke of users occasionally bringing their products to Greenlight Planet's main office, where he works on the balcony - the office shows up on a Google Map search of the city. Often Julius said these will be cases where someone has bought the product in Nairobi for their grandmother in the rural area. Walk-ins are more common and so more formal at Powerpoint down in the Industrial Area or Sollatek in Mombasa where all the business functions, including the warehouse, are on the same site and there is a member of staff to greet any members of the public. Most products however do not arrive individually like this but in a batch from wholesalers, partners, agents and company-owned retail outlets.

For distributors like SunnyMoney, Sollatek and Powerpoint there is an extra step once the product reaches Nairobi (or Mombasa) as they have to forward faulty products, or samples of, on to the manufacturer as part of the warranty process. This extra step causes a further delay for customers as the distributor might wait for a month to build up a sizeable enough batch to send on to the manufacturer. Although regretful about this Charles, one-time manager at SunnyMoney explained that:

> once they come in even before we send them out we try and manage the expectations and tell them look we 'you've given us one light we just can't take one light to them we need to do it at the end of the month'

Charles also regretted that in this time, as was the case for most companies, when a product moves from the 'field' to Nairobi users are left without a product. Jared told me that in the past when M-Kopa did not have so many customers, dealers had been able to offer interim replacements to customers but these days "they will just have to wait."

Second troubleshooting and warranty

Once the product has arrived at the main company premises the second troubleshooting begins. This troubleshooting, however, is performed by someone in a technical role, or at least a role carrying a technical title: such as technician or engineer. The second troubleshoot generally involves two steps: first, a (re-)checking of whether or not the product is within warranty and second, a (re-)testing of the problem the product has in terms of functionality or performance (which is also part of the test for responsibility). Taking these two steps in turn, this section of the chapter shows a contradiction in the use of some user interventions (physical inscriptions that help identify the product owner and so determine warranty status) and the rejection of others (when scratches or missing parts

indicate tampering). Also, despite the efforts of the first troubleshoot to resolve issues early on and close to sites of use, many functional products make it to this point, suggesting limits to the control the company has over the repair process.

The first thing that typically happens when a product arrives at the company premises is to check whether or not a product is within the warranty period. For this the majority of companies I spoke to use serial numbers on products. Walid, the workshop manager at Sollatek, explained how they check the products they receive in Mombasa:

> So for example if it starts with let's say 102014, that means it was manufactured in October 2014 so if it's anything more than three years automatically that is already out of warranty. Yeah because normally they give I think two years from date of sale or three years from date of manufacture. Yeah so, that one is one of the quick tests they can do.

During a day shadowing Julius at Greenlight Planet, the first task he assigned me was to go through a series of boxes of products and check their serial numbers against a spreadsheet. These would later be updated within a company software platform, I observed similar processes at d.light and M-Kopa. Whether or not a warranty had been activated (via SMS, over the phone or a filled-in, stamped warranty card) did not appear important in my conversation with Walid or in my checking of serial numbers for Julius, the date of manufacture was the main measure.

However, many of the products I saw in workshops had faded numbers or the labels they were on had peeled off. At this point other markers might be used, such as user-written names in black marker pen or scratched in to the casing of the product, perhaps there for when leaving at a phone-charging shop alongside other products. From the very first step on company premises then the process is subject to a degree of flexibility.

The other test for whether or not a product is 'in' warranty is also visual and looks for marks of forced entry, external damage or what the companies often refer to as 'tampering'. Any physical intervention upon the product would void a warranty. The motivation behind that intervention or reason for it does not matter. Nor does it matter whether that unauthorised intervention was made by the user or by a sales agent, fundi or other intermediary. In the company setting, the categories of fundi and user, already shown to be overlapping and changeable (see chapters 4 and 5), are further blurred. Users are sometimes blamed for the work of the fundi, not just for having taken it to the fundi. When I asked, David told me that Faulu had had many of these, products tampered by

someone other than the company technician. Amos, at d.light, recognised this too. During a day shadowing him he noticed a screw missing on a radio and told me:

> customers always take these things to the electrical engineers [mafundi] outside. But it is always easy for us to detect.

From my experience at Malo Malo such a small oversight is entirely feasible as screws fall to the floor during a repair or they are not screwed in with the same care or attention after the job is done. Indeed, Wilson and Hesbon would often pass objects to me to close up again while they moved on to the next job – indicating the lesser importance, and easier task, of closing up a product.

If the date on the serial number is wrong or there are visible signs of damage, I was told in interviews that these products are out-of-warranty. The company representatives I interviewed were rarely clear or certain about their process for these out-of-warranty products however. They can be sent back as is, users can pay for the repair, buy a replacement product (in some cases at a discounted price) or are advised to visit a fundi.

Although I was told by Gijs and others about the possibility of paying for out-of-, or after- warranty repairs and a couple of interviewees mentioned price lists for such, this is not something I observed in the workshops and warehouses that I visited. None of those interviewed were looking to make money off out-of-warranty repairs. Walid, Ramin and Gijs were all willing to forego profit telling me: “Er no we normally don’t charge for those”, “we don’t necessarily make a massive profit on, on those repairs” and “[we are] not really focusing on making massive profits on the spares”. Simon also downplayed the importance or value of making money off of a repair.

Instead most companies were servicing out-of-warranty products in order to keep customers happy. This was both in a positive sense, like Walid who told me laughing: “It’s just like a community service”. And a negative one like David who said that Faulu had to help “the more crazy” customers because “if you don’t fix his product he is going to spoil your name so you have to fix it.”. Gijs had also mentioned arguments with customers over the responsibility for problems. These positive and negative motivations could be because customers seemed to have a mixed reputation. In addition to the “more crazy ones” David also told me that “people out there, they are smart”, when referring to the various fixes users attempt on their products. Although for David and his equivalents at other manufacturers, as for me as a researcher, it is not possible to know at the company whether or not the material alteration on the product was conducted by the user or by a

fundi. Within the company process however the distinction is peripheral as the warranty would still be void.

Some products, despite being out-of-warranty are still repaired (or replaced) alongside in-warranty ones and so for free. "[S]ome cases you will just do for them" Amos told me. George and Julius both told me similar: they would repair and return products that were out-of-warranty, either for free or they would ask for a small fee to cover the (company) resources they might have used. This sort of informal transaction is an example of the similarities that persist between the company workshop and the repair clinic.

Replacing repair

If the outcome of the second troubleshoot is that the product is *in* warranty (or not but a technician shows leniency) then the product is either repaired (material repair) or replaced. Repairs of practice are not found in this location. That is if a product has a 'real' problem. The presence of such at the main company location suggests that despite the training of sales staff the first troubleshoot does not always act as the filter that companies intend it to. These are most of the time an issue with charging: the product needs to be charged fully.

This section of the chapter suggests that replacement of products is more common because companies want to guarantee quality and trust their products to deliver this more than their technician. In replacing a broken down product with a new, unsold one, companies can be confident in the performance of that new replacement product as it has passed the Lighting Global certification process and internal quality controls too. The company cannot say the same if a technician (read: human) has intervened to effect a material repair, especially if, as chapters 4 and 5 suggest, the act of repair is itself inherently inconsistent. But again this desire to keep customers satisfied and maintain a brand image has to be balanced with keeping costs down: replacing a whole product is more expensive for a company than repairing it would be and so some material repairs do happen. When a material repair is made it is usually still a replacement but at the component level. Preference is given for new spares, again for quality reasons. Although at times this is balanced with previously used parts again in order to keep costs down.

The one for one replacement of products was for some about keeping customers happy. Charles told me that it was about saving face, he did not want to "disappoint a customer,… any customer." For others the reason to replace whole products was more

about guaranteeing a consistent performance and quality in their products, Anthony told me that d.light:

> will never [repair products], because of the quality we stand on, we will never give you something that we don't believe will last you for the rest of the period we have promised.

There was also a cost-saving reason to do whole product replacements though. For Omnivoltaic it did not make financial sense to do any material repair because

> the battery represents something like 50 even sometimes even 60% of cost of the light so if the battery's gone, the product's gone, there's not a whole lot of value you can salvage by replacing the battery. So, so, so for lantern products we typically design in such a way the battery is not replaceable.

Those companies who *do* replace batteries (and other components) obviously need a source of spare parts. These come from three places: as standalone new parts, cannibalised from new stock, or cannibalised from returned products. For some, like Tropikal Brands, the only new components replaced are batteries. But in other interviews and warehouses and workshops I heard and saw companies replace panels, switches, LED boards and PCBs from new stock. I did not hear or observe of any company replacing product casings. During the day with Amos at d.light we were fitting *new* LED boards. Tropikal Brands are one of the companies who were taking components from new stock, although this was something George was working to limit because it was costing the business financially.

Martin (Greenlight Planet) and Gijs (Barefoot Power) both told me their companies design products to make replacement of parts as *easy* as possible. Martin said: "we are trying our best to make the design as simple as possible". Where earlier products had 3 or 4 wires "flying around inside" Martin said that Greenlight Planet were now "trying to make everything in to one board". While Gijs told me that for Barefoot Power repairs:

> The most you need is a few screwdrivers and a multimeter to test and a battery booster would be helpful to assess you know, overnight, if that maybe you just drained it too much, maybe it simply was faulty. Even a PCB is fairly easily detached from the system, erm, as long as you know what is positive and negative you are able to connect it back to the battery so we've done it to a point where you don't need to be a technical, technical guy to now start soldering on the connection, even if for example a weak point in the switch wire for a lot of systems, including ours, is that if you keep using it, on-off, on-off, on-off some of the rocker switches behind the lights will break, it's just wear and tear. Don't even

> bother to go look for a new rocker switch just take the cable in full and give the guy a new cable. We try to take out the whole nitty-gritty of soldering and fixing and stuff like that so that it's easier for a lot of people to simply do replacements.

I was struck during by the contradiction. Mafundi were derided somewhat, in tone and language, as being incapable yet the product was deemed easy to repair without much fiddling or tools. The difference perhaps lying in the access to spare parts, the company emphasis on, and access to, spare parts is the distinguishing feature; replacement trumps repair.

Repair at the company then although more possible than at the clinic, with greater access to new parts or pre-existing stock from which to cannibalise parts, is marked by a trade-off between the need to ensure consistent quality, the desire to keep costs down and keeping customers happy.

Repair persists

Although not always written down (as it was on the whiteboard and noticeboard at Powerpoint and Sollatek) there is a more defined process that occurs, or at least is articulated, at the company than at the clinic. Starting with a first troubleshooting over-the-phone or in person the emphasis is always on a diagnosis of responsibility and cause as much as on the nature of the problem at hand. If deemed a major problem the product is transported to the company main premises, mostly in Nairobi, for a second troubleshooting which looks even more closely at indicators of warranty (serial numbers and visible markings). The fault is sometimes logged in an Excel spreadsheet or bespoke software. Others use a more analogue system of pen, paper and sticky labels to track their products – a feature of the process that is again not found at the clinic but is perhaps a symbol and result of the far greater volumes of products moving through the company setting than the independent repair clinic. Despite the volumes little repair actually happens here though. Instead in-warranty products are replaced, with the old ones kept for spares (like they are in the clinic). While out-of-warranty products are supposed to be charged or returned un-touched to customers. Interviews and observations however suggest that for reasons of customer satisfaction and brand image some out-of-warranty products are repaired at no cost to the user.

Despite an outward formality: narrated in interviews, displayed on noticeboards, reflected in job titles and (sometimes) in the repair space or tools, informality persists.

There is variation in the process and the technicians active in it often start work casually or through a friend or family member akin to the mafundi met in the previous chapter (Chapter 5). The company's confidence in the performance of their products contributes to the neglecting of after-sales, which in turn, despite claims to the contrary in interviews opens the door for flexibility. Repair at the company is aimed at maintaining customer or partner satisfaction on the one hand and minimising cost on the other, while at the same time maintaining a consistent product quality.

This section of the chapter highlights how the processes themselves have changed over time and are continuing to do so. As companies go under, leave markets, switch suppliers introduce new products or hire new employees, their processes change. Indeed, many have already changed in the time since the fieldwork for this research was conducted. These changes are another reason why informality persists as companies are forced to be flexible.

By early 2017 One Degree Solar had closed down operations, in April that year SunnyMoney Kenya followed, as Tough Stuff (an early partner of Faulu) had done a few years earlier. Meanwhile when on a return trip to Kenya in 2017 I was told that Philips no longer had any staff in the country working on its solar products. Despite these business changes the products these companies have sold are still in homes and shops around Kenya, some of which will be in need of repair or disposal. These will likely now be serviced by the mafundi discussed in Chapter 5.

In our interview Anthony was extremely confident that d.light will still be there for their customers in the future. At the time of writing (July 2018) d.light *is* still in Kenya but in recent years has concentrated more on direct sales than third party distribution (through companies like Sollatek). Back in 2010 when Sollatek were the main distributor for d.light in Kenya they replaced components. But in our Skype interview Walid told me that this had changed in 2014 when they were instructed to replace whole products instead. When I asked Walid why this was he told me d.light had not given a reason. Walid suggested that maybe it was just "easier" for them.

Changes might also be made by the distributor rather than the manufacturer. Sollatek for instance have themselves changed suppliers in recent years, previously working with One Degree Solar they now distribute d.light, Voltlight and Niwa products. Walid had explained to me how when Sollatek had been working with One Degree Solar, their

partnership went beyond returning products to their office in Mombasa to set up service centres around the country. Walid said,

> Yeah and it worked for a while, not that efficient but er yeah it did work but anyway now we are not anymore with One Degree Solar so those service centres for One Degree are I don't think they are any more existing.

Before closing down in late 2016 SunnyMoney had also changed suppliers: moving from selling d.light and Greenlight Planet products to those manufactured by Jua Energy. All these changes in the market have led to confusion for third party retailers and users who may try and return products to the wrong company: during my day at Sollatek for instance a customer walked in with a One Degree Solar product, only to be informed that the company no longer exists, and so Sollatek no longer service their products. And on my day working with Julius at Greenlight Planet I came across a warranty card for a d.light product. Its separation from the product and being in the wrong place presumably jeopardising the chances of that product being repaired at the d.light warehouse on the other side of the city. Meanwhile Paul at One Degree Solar empathised in our interview of third party retailers having to remember the various different phone numbers and warranty processes for the variety of products they were selling.

Rather than dwell on past relationships and partnerships however most interviewees spoke of the future. Company representatives consistently downplay product breakdown as a problem in volume (there are not so many) or urgency (when we reach scale) at the moment and were confident their systems would cope, or that they would have the problem solved in the future.

Both the past changes in company constellations and companies' postponing of prioritising after-sales until some point in the future means that many products will go un-serviced, and like the sediments described in the previous chapter, these are left to fall through the gaps perhaps to enter the local repair economy of mafundi or to be disposed of. Charles conceded that the low number of returns to SunnyMoney:

> there are usually not too many, maybe in a month I would say even less than 50 [combined d.light and Greenlight Planet]

might mean that the majority of their impressive sales volumes (SolarAid, 2014a) do not find their way back to the company.

The future orientation of companies is perhaps clearest in their treatment of broken products that are not, or cannot be, repaired and of those that are replaced, or their leftover parts. These futures are the focus of the rest of the chapter.

Decorations and demonstrations

I first visited the office of Greenlight Planet in October 2014. Arriving on the second floor of an airy and artistic office block in the affluent Hurlingham neighbourhood of Nairobi, I remember being struck by the creative feel of the space; it felt much more like a design studio than an energy business or an engineering firm – a reflection perhaps of both how these solar products are conceived, marketed and the demographic they attract as employees. I had arranged a meeting with Laurens, who was leading Greenlight Planet's business development in East Africa at the time. A colleague and I sat with Laurens at a paint-splattered table and discussed product design and repair. When I next went to the office, in September 2016, I noticed a collection of old products attached to the front of the reception desk (fig. 6.5). These were not functioning products but faulty ones, re-incarnated as decoration.

Figure 6.5 The reception desk at the Greenlight Planet's head office (Author's image, September 2016)

As Adrian, a product designer, led me past the desk and in to the same glass-sided board-room where I had been almost two years earlier I noticed how many other products were littered around the open plan office. We even handled one during a Skype interview with Adrian's colleague Martin, who runs the company's manufacturing operation in China, to discuss certain design features. These products on the desks, shelves and windowsills will never be sold but exist for demonstration and marketing purposes. It was similar at d.light's headquarters in Lavington and M-Kopa had demonstration systems all over its 'campus' in Kilimani, including one installed in mock-up home in the garden of their compound. Sollatek meanwhile had even older history on display with a few Glowstar lanterns (discussed in Chapter 1) sitting on shelves around.

At Sollatek I was told of a different sort of creativity. At one point in our interview Walid laughed and told me that:

> You know, when some of our technicians are right now here are bored they will basically go to this junk, remove the LEDs, try to make up some LED light system

Intrigued I asked Walid if this was to take home with them or a bit of fun?

> Yeah a bit of fun maybe or try and link up some panels together and make a bigger panel system which is faulty because maybe you know just try and be creative with those things

Such a playful interaction with the sediments was reminiscent of the children at home, or those who picked up the pieces outside Malo Malo. Or the children who take or are given broken down solar products to play with at home. Rather than providing light or electricity, in the company office, products become playthings, artefacts of design and objects of history. Similar to some users at home, after breakdown, products become symbolically valuable rather than functionally or materially so.

In addition to being used as decorations and exhibits the remaining sections of the chapter explore what else happens to products at the company office and their warehouses; sites that in some cases are in the same place. Holding is again the dominant response to breakdown. The gap is again motivated, at least in part, by the uncertainty of the future. Similar to users at home, company representatives are not sure of what the 'right' thing to do is. Broken down products at company premises are also subject to siphoning as was observed at the clinic (see Chapter 5). The siphoning leaves the same sediments that are found across the three locations. The difference however at the company level is, as it was with repair, a matter of scale. The volumes of waste that are waiting at the company are much larger than in the home or repair clinic.

CSR, gifts and product testing

Four days before our meeting with Laurens in October 2014, the same colleague and I went to the SunnyMoney office where my colleague asked for, and was duly given, a couple of broken down solar products. If it cannot be sold, and is not kept, an old solar product can be given away. At Greenlight Planet in 2016, Julius told me that some replaced products are given away as part of 'CSR' (corporate social responsibility), he gave the example of a donation to a children's home. Julius' counterpart at d.light told me similar, he had first been drafted in to the d.light warehouse to work on a project refurbishing a series of their popular S2 lights to donate to some schools. This benevolence however escapes the tracking of the impact metric market device.

More frequently, and more systematically, certified manufacturers will use broken down solar products for testing purposes and to inform future product design. This section of the chapter shows a distinction between the fundi who holds on to products in order to

re-work them, or parts of them, in to life, versus the companies (ingénieurs) where products are held to *inform* a future creation not to be *part* of one.

Other products are sent to China or India. As we sat on the picnic bench outside his office, Anthony told me that d.light return some products to China as samples for testing and future product improvements. Anthony said that these samples could be anything from 10 to 1,000 units and were all part of the scientific process that he emphasised throughout our conversation. He re-iterated several times that "there is no gut feeling" in d.light procedures. This contrasts with Orb Energy where Ramin initially forgot that any of their products are taken out of Kenya. When I asked about faulty products he first told me that "they are still sitting here [*gesturing behind me to the other side of the office*]". It was not until the end when I asked him, as was my custom in all interviews, whether he had any questions for *me* that he told me:

> Actually for the, for the batteries by the way one thing I just remind myself, what we have done is actually that's what happened, you will not find many here, you might find but what happened I remember one day when somebody from, from India, from the factory came here, he took back the defective batteries for them to study it, to find and to discuss, take it up with the supplier for replacement also. So I remember one day he came here and the batteries that were there he took them back to, he just put them in his suitcase and brought it back, and then they were wanting to find out also what happened to these batteries and then take it up with the supplier, but that's I remember, that's what happened once.

SunnyMoney and Sollatek would also send products back to manufacturers (Jua Energy and Niwa) based in China. The same interviewees that had emphasised the small number of technical failures on their products contradictorily admitting breakdown told me of their use of failure and returns data to make changes to product designs.

On the face of it the transboundary movement of (e-)waste from an African country to China or India is in keeping with existing studies of global waste flows (Furniss, 2015; Grant and Oteng-Ababio, 2012). But crucially, compared to that literature, this flow of e-waste is both minute in volume (relative to that which is being held or stored for the future) and is *not* destined for 'informal' dismantling or recycling, at least not immediately, but rather to feed in to future product designs. Its value is held as an assembled product rather than for its constituent materials. After the testing has been done or the supplier warranty claimed, perhaps then these solar products join more visible (and documented) e-waste circuits on the edge of Chinese or Indian manufacturing districts but such movements are beyond the scope of this thesis.

I asked Huashan, the founder of Omnivoltaic, on Skype, whether Omnivoltaic returned products to Hong Kong, where he and his company are based. He told me that this would be "prohibitive" in terms of cost and so rather than bring the products to Hong Kong Huashan sends his engineers to Kenya to test the products there, typically once every three months or once 50 to 100 units have accumulated. They would only bring the products to Hong Kong in the event of a "large scale failure" citing the possible scenario of a batch of batteries. Otherwise Huashan said:

> You know we, we, at this moment we do not have a clear disposal policy because nobody is qualified to really do a proper disassembly so my suspicion is that they will just go in to the rubbish stream.

With no operational presence in Kenya, companies like Omnivoltaic have even less control over their supply chains - especially the retail segment; and so it is even harder for those absent brands to control their reverse logistics. If they do not have a warehouse, storage of waste, as more visible companies do, is not an option and so waste products are added to the local (and general) waste stream. Despite having an office and sales and technical teams in Kenya Ramin said that Orb Energy generally throw broken down panels into the office waste, entering the same rubbish stream Huashan spoke of. Ramin said that the rest of Orb Energy systems were "probably still sitting there [in the office]". Indeed there were boxes scattered all around the office where I interviewed Ramin.

Although most companies do not officially throw solar products in to the regular waste, some parts, sediments, do join other office waste (paper, food, plastic packaging *et cetera*) and other types of non-electronic solar waste such as brochures, leaflets and stickers in the general waste stream. During days spent shadowing technicians at 8 different companies and organisations I saw bits of solar products: the odd wire and bit of plastic, tossed in to the bin. I did so myself too.

The rubbish stream

I tried to find out where this office waste went. Few people at any of the solar companies and organisations knew who collected their waste, especially when they were in a shared office building. Instead I contacted the building management or, on one interviewee's suggestion, I asked the security guards: guardians not just to who comes in and out of the compound but also what, and, crucially, *when.* With a few phone numbers I collected I then set about calling and asking if I could join the round for a day.

The local rubbish stream that Huashan had referred to is the private waste collection system that serves office blocks and business compounds in Nairobi by taking their rubbish to one of the city's three main dumps. In December 2016 I spent a day with one of the companies that make up this system and collect from one of the solar companies I had interacted with.[91] Three times a week Kevo, Odhiambo and Charles (all men), employees of 'Major Enterprises' drive their truck around the south-west of the city. As I rode around town with them and helped throw (mainly) black bin bags in to Odhiambo who sorted them at the back I noticed, similar to what I had seen on the day of the clinic clear-out, that there were two other characters involved in this process. Two characters I would not have encountered had I not been on the truck: the ambulant scavenger and the watchman or security guard (also male roles).

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Although my gender helped me gain access to this site of observation, my race very once again made me stand out. My whiteness made us more visible on the roads and attracted more attention on the estates. People's heads would turn as we sped past hanging out the side of the truck and watchmen were particularly interested as to what the white guy was doing with them. Although I was part of conversations and did the same work as Kevo and the others, I only did so for one day, whereas they have been doing it daily for years. Similarly, although I looked through the rubbish I did not take the opportunity to scavenge for myself. At one point on the route we passed the house where I was staying. It was a much bigger building, on a much bigger plot and much more central than where they were staying. This is to say that while I spent a few hours with them, there was no hiding that I was closer to being a client of Major Enterprises than a colleague.

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When we pulled up to one residential compound there was a bedraggled-looking man with dreadlocks in dirty rags going through the bins. I asked Kevo if he was allowed to do that and he told me no, but they would let him. The man with the dreadlocks would collect enough plastic bottles to sell in order to buy some food to survive the day, Kevo explained to me. He also said that we would struggle to fit everything in the truck as it was so in

[91] I tried to cover all company offices but other waste companies were less responsive or less willing to accommodate a researcher. I understand however that they all operate in a similar way to that observed at Major Enterprises.

some ways the dreadlocked man was doing us a favour by reducing the waste the guys had to collect. Generally specialising in PET or glass bottles these scavengers would not deliberately seek out solar waste but in browsing for their chosen material one can imagine them, like the passers-by outside Malo Malo in Bomet, taking a solar product or panel on the off-chance that they could use or sell it elsewhere.

Although we did not see any more ambulant scavengers that day I saw and heard of several security guards or watchmen having a look through the waste themselves, with keys to access lockers and huts where waste is stored, or time to wander the compound during their shifts, there will also be scavenging that we did not witness, out with the times of the collection. Again, Kevo and the boys did nothing to stop this. And here security guards would be looking particularly for more typically valuable objects such as electronics, including off-grid solar products.

Then there was the ciphoning of Kevo and the boys themselves. The day I was with them Kevo proudly showed me a USB-phone charger that appeared to be brand new and still in its original packaging as we climbed back in to the front of the truck. He placed it on the dashboard were it would stay for the rest of the round. Kevo told me that they generally only took electronics and at the end of the day would try and sell them to retailers or mafundi in the neighbourhoods where they lived to get a bit more cash on top of their pay from Major Enterprises and the metal they sell part way through the day (again to alleviate the limited capacity of the truck).

The truck I rode with Kevo et al. was heading to Dandora, Nairobi's biggest dumpsite on the north-east side of the city. On a visit there in 2014, I had been told that no e-waste reaches there anymore because of 'the Chinese'. None of the ambulant scavengers, security guards or the Major Enterprises team are Chinese but they are definitely getting to the e-waste (and so, solar waste) before it reaches Dandora. This kind of intermediary scavenging appears in both Reno's study of a Michigan landfill (Reno, 2009) and Schiffer's work in Tucson, Arizona (see Rathje and Murphy, 2001). In counter to dominant discourses of scavenging as being motivated by survival and sustenance, Reno says that the scavengers he worked with:

> provide alternative appraisals of their labor, which have more to do with the *opportunities* afforded by other people's wastes. (32: Reno, 2009)

While the bedraggled man who goes through the bin is likely doing so for survival, the passers-by in Bomet, the watchmen in Nairobi, and the truck-riding waste worker typify the

opportunistic scavenging Reno observed at Four Corners: a scavenging that is characterised by chance and occurs alongside other, more organised or formalised, work. But once on the dump at Dandora

> Even those who live by scavenging on the world's dumps have no interest in recovering all waste materials. For example, when reclaiming copper from cables, usually by open burning, whatever is on the end of the cable (connectors, 'mice', plugs) is simply cut off and dumped. (219: Maycroft, 2015).

These are the bits and pieces that, to quote Gabrys, "…accumulate into a sort of sedimentary record" (vi: Gabrys, 2011). And these sediments wait once more, only now they do so for epic periods of time.

Waiting in the warehouse

Most replaced products or parts for most companies however do not enter the local waste stream directly but are stored in the warehouse (or equivalent if the company does not have a dedicated warehouse like SunnyMoney who were storing some stock in the office bathroom). After a morning testing and sorting products together at the Greenlight Planet office where I had previously met with Laurens and Adrian, Julius taped up the box of products we had worked through and gave it to two of his colleagues to take in a taxi down to the warehouse, on the south side of the city. Once in the warehouse the products would wait. George told me similar:

> all in all you find a chunk of the faulty products in the warehouse that one I am very sure…we find like most of the suppliers or like manufacturers who are the main distributors they still have they still have the faulty products in their warehouse.

Jared told me that M-Kopa were also holding on to their returned and unsold (i.e. previous product generations or demonstration stock):

> Ok, at the moment, they're just, they've just been stored. Every item that is beyond repair we have never disposed them. So they are just somewhere. Yeah. But, sometime back there were guys, they were working on how, we were working on how they will be disposed but we are still waiting on a word from the senior management team, yeah.

This combination of storing solar waste and working on or a discussing a more permanent plan for them was common across all interviews. Anthony told me that d.light are also storing their faulty products (fig. 6.6) but assured me that "sooner or later I'm sure we will

have a discussion of what we intend to do with them.". Not only did interviewees all talk about holding on to used solar products but they all spoke voluntarily of the future: Jared (M-Kopa) was "waiting" for direction from his managers, Simon (EcoSmart) was "looking at ways" of dealing with them and Anthony (d.light) 'will' have the discussion. Like the clinic or the home, it is a transitional state, the products are waiting in the gap between breakdown and waste.

Figure 6.6 Transitional goods: Two years of returned stock sitting in d.light warehouse (Author's image, December 2016)

And, like at home, in this gap things get lost. Similar to the lack of control identified in the after-sales processes, Gijs conceded, as did Charles, that not everything is accounted for and, like at home, things can go missing. He told me that his: "warehouse guys…don't really care whether it's 50 units or 52 units right?" Keeping track of waste, like dealing with repairs, is not a priority for certified actors.

"Recycling"

There are two other places broken down products moves to within Kenya: Associated Battery Manufacturers (ABM) and the WEEE Centre. Both, based in Nairobi, can be identified as recyclers. The first, ABM (more commonly known as Chloride Exide after its leading product: the Chloride Exide battery), is the oldest and biggest battery manufacturer in Kenya (see Chapter One for some background).[92] As a result of the volume of their business and standing in the market Chloride, as they are locally known, have established themselves as the leading recycler of lead acid batteries in the country as well. Tropikal Brands gives its waste batteries from Philips solar products to Chloride Exide.

For the rest of the materials, the sediments, George told me: "we [Tropikal Brands] have just accumulated" because having only started distribution the previous year, in 2015, they "have never received as much." George, like his peers at other companies, plans to look for a recycling company to collect these other parts in the future.

The second recycler, the WEEE Centre, whose name bears reference to EU Directive 2012/19/EU on Waste Electronic and Electrical Equipment (WEEE), was set up by a Belgian NGO called World Loop.[93] Set up to deal with all electronics, rather than just batteries, the WEEE Centre have signed memorandums of understanding (MoUs) with many of the leading certified companies in the last couple of years. Almost as soon as we had sat down for our interview Gijs told me how the WEEE Centre collects Barefoot Power's used and replaced batteries once a month. 2 to 3 months after which, he told me cheerfully, they "receive a disposal certificate indicating that we have disposed of it in a friendly way." At the time of my fieldwork SunnyMoney, Greenlight Planet, d.light and M-Kopa were all also using the WEEE Centre. Such apparently responsible disposal however is not yet captured in the market device of the impact metrics.

I first visited the WEEE Centre in October 2014. I was in contact with Seth, the manager, again in 2015 as part of my role on the GOGLA Sustainability Working Group. After much effort in 2017 I was able to spend a day with Seth's team at their re-located

[92] I did not engage with Chloride Exide beyond an interview with Joseph Muthoka (the Country Manager for renewable energy) regarding the history of the industry in Kenya (see Chapter 1). The brands at the centre of this thesis are increasingly using lithium, rather than lead, based batteries and so the recycling service offered by Chloride Exide will become increasingly redundant for the off-grid solar industry. Similarly, as mentioned in Chapter 1, the solar systems involving Chloride Exide batteries are sold and marketed in a different way and with different benefits than those of the pre-packaged, plug-and-play market that the thesis concentrates on.

[93] World Loop works to set up e-waste management projects in Kenya, Tanzania and Burundi (World Loop, 2013).

facility in Embakasi. After the typical tour, an updated version of what I had been shown in 2014 I spent the day with Seth's team manually dismantling and sorting a pile of electronics. Although seen by the solar companies who send their waste there as a 'recycler' the WEEE Centre does not do any material processing at this site but instead sells fractions for processing elsewhere some locally and others abroad. The most telling moment of my day there however was when I asked one of the worker's about the panels, which he told me were just being stored. Some solar waste then is moved from waiting in the warehouse to waiting at the 'recyclers'.

Waiting with waste

Disposal at the company can, like in other locations, take various forms: it can be held on to, sent away, given away, thrown away, siphoned off, stored or 'recycled'. The crucial difference in the company setting is the volume of products being dealt with. Like with repairs, there is much more disposal happening at company offices, warehouses and workshops. Although sedimentation does occur here through the cannibalising of old and new products, much more of that which is disposed takes the form of whole products, rather than the bits and pieces that are secreted from homes and repair clinics. Despite differences in size and frequency however, like at the home and the clinic, most waste from the company waits. It waits because companies are unsure what to do. There is a constant uncertainty of waste - people do not know where it goes, what should happen to it, what they should do with it, or sometimes whose responsibility it is. So although waste is something that remains, the remnants of a previous event or action, and is studied by archaeologists or garbologists, this waiting means it is also a thing of the future.

Companies send products back to factories in China and India not only to see what happened (in the past) but also to see what can be done next time (in the future). In doing so broken down products at the company linger longer in the solar assemblage than those at home or the repair clinic. The same is true of the lights on the Greenlight Planet desk that, like the paint-splattered tables made of old doors and window frames, serve an aesthetic purpose in the present but also act as a museum to previous designs of the company.[94] When I left BBOXX, my former employer, I was given an out-of-production product not to light my home but as a memento of my past work experience and something

[94] When the products on the desk are taken down they will presumably move in to the waste stream from the office towards one of Nairobi's dumps, be given to or taken by employees, or sent on to the company warehouse in the south of the city and perhaps later moved on to the WEEE Centre.

to show others. I keep it for the same reasons. I keep it for the future like Mac, one of Reno's informants, keeps his "pleasing" diamonds from Four Corners (Reno, 2009) and like some survey respondents keep their solar lantern; as a *kumbusho* (memory) of the past.

This chapter (and the thesis as a whole) have, necessarily, if regrettably, followed a linear structure. An attempt has been made, however, to stress the recursivity of broken down products that escape a linear progression from consumption to dumping or recycling. Objects have been shown to move into and out of 'the gap' between consumption and waste. In the company setting waiting in the gap could mean standing on the shelf in an office or sitting in a box in the warehouse only to come back as a gift or as the subject of testing. Rather than think of end-of-life electronics then, perhaps it is more accurate to talk in terms of afterlives (Cross and Murray, 2018). Similarly, the structuring of the thesis around discrete locations has side-lined their peripheries and the movements between them. It is only in attending to these margins however that one can see the opportunistic scavenging of the child, the passer-by or the watchman and the sediments that fall away along the way both of which are absent from academic and industry discussions of e-waste.

The conclusion that follows suggests that the repair and disposal of off-grid solar products, as part of a particular historical and contemporary context within International Development, may hold insights for better development practice.

Conclusion

Development and the still broken world

Development by bricolage

International development, as articulated in global initiatives such as the Millennium Development Goals (United Nations, 2015b) and more recently the Sustainable Development Goals (SDGs) (United Nations, 2015a), is concerned with reducing global inequality in areas such as health, education, energy, hunger, poverty and gender. Such initiatives, and the communities of practice and research that they create and are created by, in their very existence acknowledge that the world is not in an adequate state; it is broken. The pursuit of these development goals in bi- and multilateral policies, non-government programmes and increasingly business opportunities are a response to that broken world. We can think of these responses as attempts to repair. And so development, like repair studies, as starting from breakdown.

However, unlike repair, development efforts rarely recognise that any unbrokenness they ever achieve will be temporary because future breakdown is inevitable. Development tends to work with new plans and new ideas rather than remnants and remains which it may associate with failure (the world is still broken) and so seek to distance itself from. In looking forward then, as an ingénieur might, development denies itself the capacity to see that the world will keep on breaking and its best repairs (through infrastructural investments, economic restructuring or innovations at the base-of-the-pyramid) can only ever be temporary. The ingénieur, Lévi-Strauss writes,

> is always trying to make his way out of and go beyond the constraints imposed by a particular state of civilization (19: Lévi-Strauss, 1994)

while the bricoleur, by inclination or necessity, stays within them. Might international efforts to reduce global inequality be better served then by adopting the approach of the bricoleur: acknowledging the inevitability of breakdown and working from the remains of previous efforts?

That not everyone in the world has regular, reliable or proximate access to electricity is one way the world is broken. In July 2016, while I was in Kenya conducting the research for the thesis, the government released new electrification figures estimating coverage at 56% nationwide (Bungane, 2016), this was a big jump from 42% the previous year (World Bank, 2018a). The Kenyan government's response to the lack of electricity access is to extend the grid. There was a day the previous month however when a monkey had tripped out the electricity grid for most of the country (Karanja, 2016) so one can question how reliable this connection is for the 56%. Reliable or not, the 56% does not count off-grid sources such as the solar products that have been studied here. The off-grid solar product is an alternative fix. Financed, advocated and promoted by international development actors, notably the World Bank through its Lighting Global programme, the off-grid solar product is an example of what Collier and colleagues have called a 'development device' (Collier et al., 2017). But whether by monkeys or by other means development devices too break down (Collier et al., 2017).

This thesis set out to answer the question:

> What can breakdown and responses to breakdown of off-grid solar products, distributed through market approaches, tell us about development practice today?

The incredible growth in the sales of these things, from 0.2 million products in 2010 to 26.2 million in 2016 (11, 14: Bloomberg New Energy Finance and Lighting Global, 2016; 58: Dalberg Advisors and Lighting Global, 2018), makes this an important question to think about. For more and more people infrastructure takes the form of a development device (or humanitarian good) like the off-grid solar product. And, leading in terms of market age, sales volumes and penetration Kenya is an important place in which to answer it.[95] In order to do so, three sub-questions were outlined: *How does the market distribute off-grid solar products? How, where, when and why does breakdown occur?* and *What happens in response to breakdown?*

The thesis used assemblage thinking to answer these questions. Assemblage thinking helps highlight that although physically and materially less visible than grid electricity, off-grid solar products still require a series of connections in order to reach sites of use and once there to remain in use. The thesis based its understanding of assemblage

[95] Kenya is the only country where off-grid solar products are known to be in over 50% of households which are off-grid or have unreliable grid connections (17: Dalberg Advisors and Lighting Global, 2018).

on the work of Nail (2017). The assemblage, Nail suggests, is defined only by its relations and not by any essence to its subsisting parts or "fragments" (22-23: Nail, 2017). Its features are contingent, not eternal. The fragments of the solar assemblage (Cross, 2012) include panels, batteries, LEDs and circuitboards of the products as well as the investors, manufacturers, distributors, technicians, users and mafundi along with all the various organisations and institutions they represent and constitute.

Thinking in terms of relations drew attention to the organising regimes of quality standards and impact metrics that make and measure the off-grid solar market, its products and its actors. The new material products, new companies and new business models that the market devices qualify and quantify show the off-grid solar market to be the work of an ingénieur rather than a bricoleur. These introductions (or impositions) however, like with any infrastructure, still end up integrating with pre-existing local contexts. In this case the solar products were shown to interact with the wider (and older) electronics market in Kenya as users treat products the same as other electronics, turn to mafundi in cases of breakdown and fit the products in to their existing household disposal routines as well. This integration undermines the ingénieur's approach and creates problems when certified actors seek to introduce their own repair and disposal regimes as well. The argument of the thesis is that the use of development devices, and what Redfield refers to as the "alchemy of innovative design and empirical monitoring" (158: Redfield, 2012), serves to limit bricolage; an approach that ironically has been shown at the home, the clinic and the company, is how people in Kenya already make the solar assemblage work for them. Universal energy access may come sooner should development facilitate bricolage by drawing more from the bricoleur than the ingénieur.

Development scholars Escobar (1995) and Ferguson (1994) both independently write about the need to pay attention to development at the local level. It is there, they argue, that the intentions of development planner and practitioners is hybridised and resisted. The bricolage engaged in by users at home, repairmen in clinics and technicians at companies appear to support the claim of hybridisation and while the degree that their resistance is conscious or intended could be contested there is little doubt that the actions of the bricoleur frustrate the aims and goals of the certified actors. This thesis is not a rejection of the off-grid solar industry and its markets either global or in Kenya but instead, in keeping with how Chakrabarty analyses modernity and Ferguson development, the thesis

has sought to make visible the origins and workings of the industry and thereby further understanding of it.

What has been shown in this thesis is that bricolage is a more distributed, environmentally friendly and socially sustainable strategy for extending and maintaining access to electricity. Not only this but in adopting the principles of bricolage it is suggested we might also fix some of the political problems inherent to development and well documented by the likes of Escobar, Ferguson and Mosse. Chapter 3 demonstrated how breakdowns can be creative and formative, there are suggestions this could extend to the macro level as well. It is not just a materially transformative moment but potentially a politically transformative one too. This in part because knowledge is generated through repair (see Chapter 5) and if afforded greater recognition such knowledge could inform not only new product designs (material) but perhaps better market standards (material and political) or even more equitable approaches to development (political). Development has been encountered (Escobar, 1995) and cultivated (Mosse, 2005). Now it must be fixed.

The conclusion begins with a recap of the preceding chapters beginning with Part I's discussions of the historical development of solar PV in Kenya, the establishment of a certified market through market devices and the various types of breakdown. This is followed by an overview of Part II's movement through the responses to breakdown that take place at home, at the clinic and at the company. The empirical implications of the thesis are then discussed; these include suggestions for the neutral servicing of products and the provision of spare parts. The theoretical contributions of the thesis follow next. These are an increased understanding of the 'gap' between consumption and disposal within discard studies, a renewed emphasis on the role of bricolage in repair studies and to use both ideas to work towards a humbler, and perhaps more effective, practice of development. The conclusion ends with a look at how these contributions might be built on in future research; using repair as a heuristic to understand other development devices in areas of health, cooking, water, and sanitation for instance.

Recap of chapters

This thesis has followed off-grid solar products in Kenya through time from the 1980s to now, and then space through sale, use, repair, and disposal. Chapter 1 showed how the applications of solar PV in Kenya to a large extent mirrored the trends of international

development over the same time: from local, appropriate, engineered solutions to innovative, sustainable businesses. The chapter argues that the influence and role of outsiders has cast Kenyans in the role of users and beneficiaries. Although initially visible along racial lines this has been complicated in recent years by the increased presence of middle class Africans in more senior positions. Similarly, where initially the outside was America or Europe, China has come to play an increasing role in the assemblage. The industry has however been consistently dominated by men. While the history recognises continuities in that sense, there is also a key change in the shift from the bricolage of the early pioneers to the ingénieur's approach of more recent interventions.

Chapter 2 set up the contemporary market in two parts: certified and non-certified. The certified market is made and maintained through two main market devices: quality standards and impact metrics. The devices do not allow for quality of assembly or service, nor do they acknowledge the material longevity of solar hardware and its likely negative environmental impacts. The chapter supports the conclusions of Collier et al. that "little development devices", in this case off-grid solar products, "require and entail the assembly of new kinds of expertise, new visions of a better future (whether for individuals, communities, or nations), new articulations of populations, and new instruments." (Collier et al., 2017). This supporting labour, that brings the impact investor and testing laboratory as new sites and actors into the assemblage, again suggests an ingénieur's approach whereby the certified actors seek to impose a whole new system into Kenya rather than engage with existing local ones.

The expanding solar assemblage however breaks down. Chapter 3 worked with a relational understanding of breakdown to describe the many and various types of breakdown that occur: from vehicle accidents to company closures. Demonstrating that not all breakdowns are material and that not all breakdowns create waste the chapter used Hetherington's articulation of the 'gap' to account for the delay in time and inconsistency in actions that occur after breakdown. The conditions, locations and types of breakdown were shown to be integral to shaping the possible options for responses to it. Responses including doing nothing, for instance when actors were immobilised by uncertainty.

Chapter 4 argued that the options available at the moment breakdown is realised are shaped by the image of the user that is portrayed by the certified market. The certified market's understanding of what use is or should be does not include repair. Despite the best efforts of certified actors (donors, funders, NGOs and companies) to the contrary, the

chapter demonstrates that repair occurs at home in two ways: through changing *how* the product is used (repairs of practice), and affecting physical changes to the product (material repairs). The argument begun here is that trial and error, the use of resources 'at-hand' and inconsistency in outcome (and functionality) all point to repair as a form of bricolage (Lévi-Strauss, 1994).

Acknowledging however that repair at home is limited and infrequent the chapter also looked at other responses to breakdown. Informed by a survey of users the most common response is to hold on to broken down products. This holding is understood as a 'gap' between breakdown and disposal. The range of responses users make to breakdown and the variety of things that can happen in and after the gap are better understood by thinking of afterlives rather than the dominant framing of end-of-life electronics (Cross and Murray, 2018). Products were seen to be used as decorations, toys, and teaching tools or sold for scrap, thrown down the toilet or users try to get them repaired by someone else.

That someone else is the fundi – the central character of Chapter 5 and a further addition to the solar assemblage. Fundi is a Swahili word to describe a skilled individual who works with their hands, in this instance to repair electronic and electrical things. Mafundi (plural) are almost exclusively men, no female mafundi were met during the course of this research. Based on participant observation with several mafundi in the town of Bomet the chapter showed that they, like users, are engaged in bricolage. Although doing a lot more repairs and doing more material repairs than were found at home, the fundi proceeds in much the same way as the user, through trial and error, drawing on previous experience, using existing parts and prioritising functionality over aesthetics. What makes the fundi distinct is the difference in their motivations. Rather than repairing for pragmatic reasons (as users do), for joy, political protest or environmental beliefs (as the literature suggests others do), the mafundi in Kenya work to fix things so as to provide for their families, for economic reasons.

The fundi's work, and his constant desire to keep costs down, necessitates that he holds on to a lot of broken down products from which to draw on in repairs. Through the process of bricolage however bits and pieces of these products are not used and, for the fundi, are useless. The chapter tracked these bits and pieces, or sediments (Gabrys, 2011), as they move out of the repair clinic. Prefaced again by a period of waiting the chapter shows a similar range of afterlives as found at home with sediments of solar products being sold as scrap, siphoned off by passing children and adults, burnt by the roadside or dumped

on the edge of town, reaching as they do so the outer reaches of the solar assemblage forming from breakdown new relationships with materials of comparable composition or with elements in the ground and atmosphere.

Chapter 6 left Bomet and returned to Nairobi where the certified actors have their offices, workshops and warehouses. Where independent repair (by the fundi) was motivated by making money, repair at the company is driven by the desire to *save* money. If, after a first troubleshooting over-the-phone or in person, a product is deemed to have a 'real' problem (not just 'incorrect' usage) it is sent to the company premises for a second troubleshooting. At which points products are either returned untouched (if out-of-warranty), replaced or repaired. Despite the outward formality of a process: narrated in interviews, displayed on noticeboards and reflected in job titles, the chapter shows that through recruitment and training of technicians as well as the work itself flexibility remains and bricolage is observed. That all technicians bar one were women is another commonality across the two contexts.

Another element that is constant in the company setting is waste. The chapter returned to waste for a third time to follow the products and sediments as they leave company offices, workshops and warehouses towards rubbish dumps, recycling facilities and manufacturing operations in Asia. Some products and sediments leaving the solar assemblage by moving in to chains and flows of waste and material processing and others lingering longer in it by waiting in company-managed spaces or travelling on to inform future product design. The chapter showed however that holding is again the dominant and first response to breakdown and is again motivated by the uncertainty of the future: similar to users at home, company representatives are not sure of what the 'right' thing to do is. Siphoning, as observed at the clinic was found again here. The main difference at the company level is, as it was with repair, the far greater volumes that are being dealt with. Less interested in bricolage the company has less need to keep parts and products for future use.

Contributions and implications

> Declan: I don't know if you wanted to ask me anything or? Hmm?
> Wilson: What I want to ask?
> Declan: Yeah
> Wilson: If you finish your, your school, your plan?

Wilson was not the only person to ask me this question. Many of my research interactions concluded with a respondent asking me where this information was going, what it was for, what I will do afterwards. Meanwhile journalists, investors, practitioners and other students, learning of this research project through other means (blog, Twitter, conferences etc.), contacted me to ask for practical advice as to what they could do to improve the situation 'on the ground'. This section of the conclusion seeks to answer such questions by articulating the empirical implications and conceptual contributions of the thesis.

The empirical implications of this thesis relate to various actors in the solar assemblage, but particularly to practitioners within the off-grid solar industry. On the subject of breakdown for instance, Chapter 3 suggests that manufacturers and distributors of solar products can work to reduce breakdown not just through improving their products materially or their manufacturing processes but crucially in considering non-material phenomena as well. Companies should recognise that how they design their businesses, as much as their products, has a bearing on breakdown. One suggestion is for actors to address the use of casualised labour which contributes to accidents in the warehouse and on the road. Actors might also consider a more phased approach to the introduction of new product generations that allows for previous ones to still be sold (rather than written off) or ensuring that those new generation of products are compatible with the existing ones (rather than needing to be replaced).

Certified manufacturers could still work, as they already are, on improving product design to reduce the frequency of premature breakdown. But even here they should consider non-material parts of the assemblage such as theft, and the threat of it. This might lead to designing products (and panels) to be less visible or less portable. In terms of more typical factors in product design Chapter 4 suggests that thinking about how products might better cope with wind, force and impact should be priorities.

Designers might also consider not just working with users and usage to learn about how a product should be or about what has caused a product to breakdown or testing new iterations with them but speaking to those involved in the afterlives of solar products such as mafundi and waste collectors as to how their livelihoods could be improved through product design: i.e. making products easier to disassemble.

Working within the framework of the certified market (and its devices) changes to the quality standards and impact metrics could reflect these suggestions or drive them. A measure for 'theft-proofing' in the quality standards for instance could force manufacturers

to make products more suitable to the actual, not imagined, manner of their use. Similarly, a commitment to not employing 'casuals' in their supply chains could reduce breakdowns in that area too. Further, acknowledging and encouraging the potentially positive impact solar products have for repair and waste livelihoods could be factored in to future versions of the impact metrics.

Given that the emphasis for manufacturers is on reducing breakdowns rather than accepting that they will occur and so planning or preparing for the responses to that breakdown much could be done to encourage manufacturers and distributors to better prepare for the inevitability of breakdown.

When I told Wilson I was not sure what I would do after my PhD he suggested that I open a repair shop in my country. While this would be beyond my still limited repair abilities I had thought of a business sourcing generic parts for solar products and distributing these among solar retailers in Kenya (see Murray, 2017). Chapter 5 demonstrated that repairs in the clinic are limited due to lack of available spare parts and so one application of its findings could be to provide these. Particular parts to focus on would be those that are handled on a daily basis such as the switch and cables (especially their connector pins) as well as the battery. These parts could allow mafundi to focus on repairing the generic (non-certified) solar products. Alternatively, or in addition, mafundi could specialise in out-of- (or beyond) warranty repair and in servicing the certified products of companies that close down or leave the country. A more extreme option would be for certified companies to give up their in-house servicing and repair operations completely thus making space for the existing repair economies.

If not this and if not through an independent business as I suggest in the above referenced essay, then there could be scope for the establishment of certified neutral service centres that only repair solar products but cover all products regardless of brand or retailer. Willis at KIRDI was a proponent of such a solution and Cliff at KEREA told me it was something his association had been discussing with its members. In one particular meeting Cliff recalled KEREA members had been complaining that they were "losing a lot of money with this forward and backward logistics" moving products from the field to Nairobi and often back again when problems turned out not to be 'real'. One suggestion to resolve this Cliff told me was "to have Energy Centres where we can have people repairing these kind of products." This would mitigate problems of third party retailers, who sell various different brands, not being able to remember or follow the details of multiple different warranty

processes that Paul from One Degree Solar had warned about. A 'neutral', possibly EnDev sponsored, service centre could also catch those products lost in changing constellations of companies, distributors and financial partners. It would however not be popular with manufacturers, George at Tropikal Brands for instance expressed concern in our interview about somebody else (outside of the company) opening up 'your' products. Whether the provision of parts was sponsored or generic both would benefit from the removal of taxation on spare parts, distinct from that of appliances and accessories.

Regardless of how repairs might be facilitated, as has been reiterated throughout the thesis, sometimes breakdown is unrepairable or the conditions of the breakdown (its location, timing, possession etc.) preclude it for being repaired and so other responses occur. In preparing for such cases, and for the sediments from repair that cannot be used again, chapters 4, 5 and 6 suggest that more awareness-raising is needed to counter uncertainty and inform companies and users alike how best and where to dispose of their broken products (and parts of products). Recognising that disposal was still a "grey area" for the industry Cliff spoke of the need for more research in to it, he said,

> Right now we have a lot of, tonnes of tonnes of off-grid lighting kits that are just in the house, they are not working and people don't know where to, to dispose them, they don't know if they will. So it's a, it's an opportunity there.

Although Wilson et al. (2017) see such 'hibernation' as a barrier to e-waste management in the UK context it does also buy concerned parties some time in the Kenyan context to establish the necessary processes and facilities.

As the certified market turns to occupy itself with end-of-life questions around off-grid solar products it will need to know more empirically about where and what currently happens to them. They will soon recognise as Cliff did, the gap and that waste waits in it, and that as Chapter 1 showed, this waiting could be as long as 30 years or more. Cliff's idea of KEREA-sponsored energy centres could also operate as sites where users bring products for disposal.

The risk however is that the certified market's response to greater involvement in end-of-life matters looks set to once again be that of an ingénieur – introducing a new system of product collection and processing rather than looking to integrate, as a bricoleur might, with existing networks of material recycling. Furthermore, the trend of discussions by certified actors in workshops and reports is towards recycling rather than the other options to reduce waste or extend product lives (see Cross and Murray, 2018). Such

approaches also match with Millington and Lawhon's findings: their review of discard studies in the Global South finds a "continued salience of neo-colonial relationships" which produce "projects developed from external notions of what waste is and how it should flow" (1051: Millington and Lawhon, 2019). These external notions often lead to the exclusion of those already operating with and depending upon waste (see Gidwani and Reddy, 2011 for an example from Bengal, India). Apart from this postcolonial critique there are practical challenges to the establishment of solar waste recycling such as the difficulties of ensuring collaboration between rival companies. Much like George's concern about third-party repair (above), companies see waste management as a difficult area in which to collaborate because it involves sharing or revealing information around product return and failure rates. The same rates that were so consistently downplayed to me in interviews are deemed 'sensitive' information that companies are wary of their competitors having access to or being aware of.

The conceptual contributions of the thesis are to increase to our understanding of the 'gap' between consumption and disposal within discard studies, to re-emphasise the role of bricolage in repair studies and to use both ideas to work towards a humbler, and perhaps more effective, practice of development.

The understanding of breakdown outlined in Chapter 3 helps conceptualise the gap as being the result of a broken relationship. That new relationships form and so end the gap help explain why the gap is such an elusive concept that is sometimes hard to locate in time or space or be able to define with any accuracy given features such as the inconsistency of its length.

Working with these understandings of breakdown and the gap could bring new life to the use of bricolage in repair studies. As the bricoleur's work is to make new connections and so end the gap. But the gap itself perhaps having been active in the time since the breakdown and so altering the elements that the bricoleur combines. That things change during the gap may be another explanation for the inconsistency of bricolage in terms of aesthetics and functionality.

A third area where this thesis has made a conceptual contribution is in bringing the concept of market devices, examined in Chapter 2, into places and activities post-consumption. The constraints faced by a repairman (or woman) or waste worker by product design are well known but their connection to market arrangements has been less

studied. Similarly, that devices, particularly quality standards, shape goods and people simultaneously is reasonably established. The case of off-grid solar products however suggests that this shaping may extend even further to shape the types of waste a market produces and the types of people (and work) that exist after consumption.

The task now is to test these conceptual contributions to the study of markets, infrastructure and repair with new empirical data in other areas of international development.

Future research

The devices shaping the market could also be seen to shape research agendas. Most existing research on the off-grid solar industry has concentrated on studies of social impact, technology and finance. Where post-consumption questions have been addressed, in a series of Masters projects, the focus has been largely on recycling, particularly of lead acid batteries (Pepinster, 2012; Batteiger, 2015; Turing, 2015; Cervantes Barrón, 2016; Verhoef, 2016). Yet this thesis has shown there are other reaches of the solar assemblage and visited them. These peripheries – when the assemblage breaks down, or interconnections – when it melds with another assemblage, could provide scope for future research. Some of them are mentioned now.

The thesis has told the story of one good in one country but breakdown, repair and disposal are equally relevant to other development devices like mosquito nets, clean cookstoves, glucometer foils and filtration systems. Objects that like the solar product are offered as boxed or packaged solutions, yet rely on their own assemblages of actors and ideas to make them work, until their inevitable breakdown. More study is needed to reach a more critical understanding of what these objects do beyond their immediate contributions to fix broken health, energy and agricultural infrastructures. Not being electronic suggests there will be no fundi involved in these other assemblages, or at least not a *fundi wa TV na redio.* One starting question then might be: does more repair at home happen for these other devices?

Alternatively, future research could stay with the solar product to explore its use in humanitarian settings, corporate donation programmes or informal settlements and the use of solar products in urban environments that have not been included here. Such angles would also allow for examination of the role of large INGOs and UN agencies and their bulk

purchase and distribution. Are the dynamics of breakdown and responses different in these humanitarian or urban settings? In the refugee camp or on the tea plantation does the gap still hold?

There are also some manufacturers and distributors that were not included in this thesis and other countries in which the questions of this research could be asked, perhaps somewhere like Malawi where the market is less developed or West Africa where industry and academia have been less active. If looking to other markets, one might compare to this thesis and ask how much of it has been specific to Kenya?

Follow-on research could expand the sites of the multi-sited ethnography in other ways too such as following solar waste produced at manufacturing and testing sites in east Asia. Fieldwork in places such as China could open up greater access to and understanding of the non-certified market which has been covered less here. How do manufacturing processes contribute to breakdown? What does the distinction between certified and non-certified look like there?

Staying in the countries of use more research could follow more rural materials trading and product repair such as door-to-door ambulant waste collectors or the village fundi. Are their practices distinct from their town-based counterparts? How do they connect with the networks articulated here?

Another avenue to follow is the increasing number of appliances that solar lanterns, and solar home systems in particular are connected to such as TVs and fans. There is already an international programme being led by DFID to "accelerate the availability, affordability, efficiency and performance" of high-efficiency appliances. The Low-Energy Inclusive Appliances (LEIA) programme will run awards, develop product standards and measure impact of the solar-compatible appliances (DFID, 2018). Its resemblance to the Lighting Global programme is uncanny. Might LEIA though, like Lighting Africa, neglect the material legacy and material longevity of its efforts?

Glossary

baisikeli	bicycle
chai	tea
chuma	metal
(ma)fundi	a skilled technician or artisan
(ma)gari	vehicle(s)
jua kali	hot sun/informal sector
kidogo	small
Kikamba	Kamba language
kikapo	a basket made of pandanus leaves
kufundisha	to teach
kufunza	to learn
kukata	to cut (can also mean to come loose or disconnect)
makumbusho	memory
mandazi	a deep-fried bread, similar to a doughnut
matumbo	beef tripe
mzungu	white man/foreigner
bao	wood
nguo	clothes
omena	Silver Cyprinid fish
piki piki	motorbike
redio	radio
shamba	field or farm
stima	electricity
taa	light, lamp, lantern
ufundi	skill
wa	of, from

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